

# Draft

## Evaluation of Restoration Alternatives for the Northwest Fork of the Loxahatchee River



**South Florida Water Management District  
Watershed Management Department  
Coastal Ecosystems Division  
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**FLORIDA  
State Parks**  
*...the Real Florida*



## CHAPTER 1

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# Chapter 1: Overview

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## PURPOSE OF THE PLAN

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The unique ecosystem of the Northwest Fork of the Loxahatchee River, with its quiet beauty, has captured the attention and imagination of residents and visitors, agency and community leaders for many years. Over time, the adverse impacts of the changes made within the watershed, along with sea level rise, have become evident. It has been widely recognized that the current dry season flows to the Northwest Fork are insufficient and damaging to the ecology of this part of the river system.

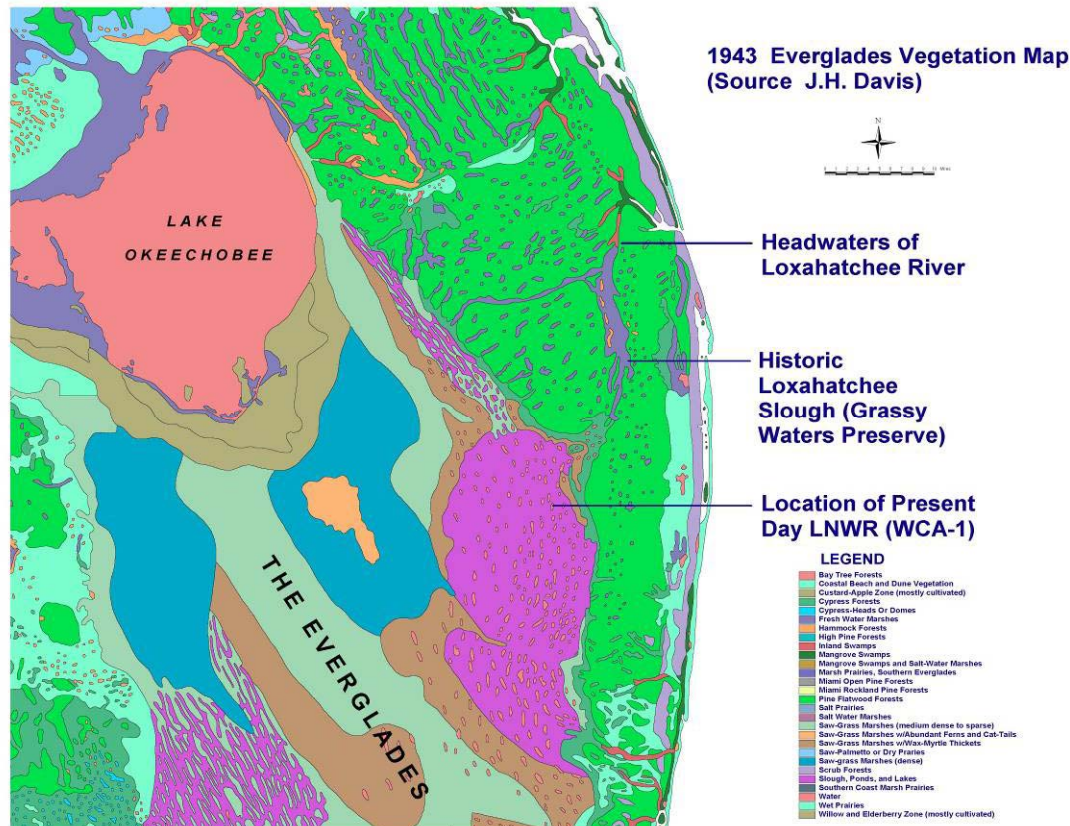
Historically, most of the Loxahatchee River Watershed was drained by the Northwest Fork. Headwaters of the river originated in the Loxahatchee Slough and Hungryland Slough (**Figure 1-1**). Today, much of the watershed has been impacted by the C-18 Canal, which has diverted much of the surface flow from the Northwest Fork to the Southwest Fork of the river and by the stabilization of the Jupiter Inlet, which has allowed tidally transported salt water to intrude into freshwater reaches of the Northwest Fork.

Prior to the 1940s, the Jupiter Inlet periodically opened and closed to the Atlantic Ocean as a result of natural storm events. Since 1947 the inlet has been kept permanently open, and is presently maintained by periodic dredging (USACE, 1966). The permanent opening of the Jupiter Inlet is one of the main reasons the primarily freshwater system of the Northwest Fork has evolved into a tidally influenced system. During the past 58 years the vegetation along the river corridor in the Northwest Fork has changed from freshwater floodplain swamp to mangrove forest due to the saltwater intrusion from Jupiter Inlet and the reduced freshwater flows to the Northwest Fork.

Other major changes that took place over the last 100 years were the construction of canals and levees for drainage and flood protection. Construction of small drainage canals in the early part of the Twentieth Century and construction of the C-18 Canal in 1958 diverted freshwater flows from the Northwest Fork to the Southwest Fork of the Loxahatchee River where it discharges to tide through S-46, a remotely operated, gated structure.

In response to identification of these problems, remedial actions have been taken by many agencies, state and local, which have contributed improvements to the Northwest Fork of Loxahatchee River. In 1982, a lawsuit was filed by the Florida Wildlife Federation (FWF; **Appendix F**) concerning the detrimental effects of the C-18 diversion. As a result, the SFWMD and the FDEP entered into a Consent Decree to provide 50 cfs to the Northwest Fork “subject to the presence of available water supplies.” The SFWMD constructed the G-92 to reestablish the connection through the Loxahatchee Slough, through the C—18, to the Northwest Fork. In addition, a 1989 agreement between the South Indian River Water Control District, the SFWMD and the Loxahatchee River Environmental Control District (LRD) addressed the operation of the G-92 structure in terms of providing 400 cfs flows to the Northwest Fork when feasible and to allow flood waters to backflow to the C-18 under certain conditions (**Appendix G**).





**Figure 1-1.** 1943 Vegetation Map of the Loxahatchee River Watershed. Source: Davis (1943) Vegetation Map of Southern Florida, Florida Geological Survey Bulletin 25, Figure 71.

In April 2003 the South Florida Water Management District adopted Minimum Flows and Levels Rule, Chapter 40E-8, F.A.C. with a minimum flow (MFL) for the Northwest Fork of the Loxahatchee River. It was recognized that upon adoption, the SFWMD would be unable to meet the MFL criteria for the Northwest Fork during dry periods. Therefore, as required by legislation, a Recovery Strategy was incorporated into the Rule, which included a commitment by the SFWMD to develop, in partnership with the Florida Department of Environmental Protection, a practical Restoration Plan and goal for the Northwest Fork of the Loxahatchee River.

The purpose of this plan is to identify restoration alternatives for the Northwest Fork of the Loxahatchee River and its corridor. The plan will document the data collection and analysis conducted, identify models and other analytical methods used in the development of the plan and describe the constraints and assumptions used by the staff of the South Florida Water Management District (SFWMD), the Florida Department of the Environmental Protection (FDEP) and Jonathan Dickinson State Park (JDSP). The plan will address the problems faced by the ecosystem of the Northwest Fork, describe the constraints of the existing water management system, and explain the evaluation of the restoration alternatives. It will provide a foundation of the best available scientific and technical information upon which appropriate dry season/wet season flows or hydrographs can be based. A careful balance of timing and distribution of flows will be provided.

The Loxahatchee River is generally referred to as the “last free flowing river in Southeast Florida.” In May 1985, 9.5 miles of the Northwest Fork of the Loxahatchee River was federally designated as Florida’s first National Wild and Scenic River. In addition, different portions of the

river and estuary are designated as an Aquatic Preserve, Outstanding Florida Waters and a state park. The Northwest Fork represents one of the last vestiges of native cypress river swamp within southeast Florida. Large sections of the river's watershed and river corridor are included within JDSP, which contains outstanding examples of the region's natural biological communities.

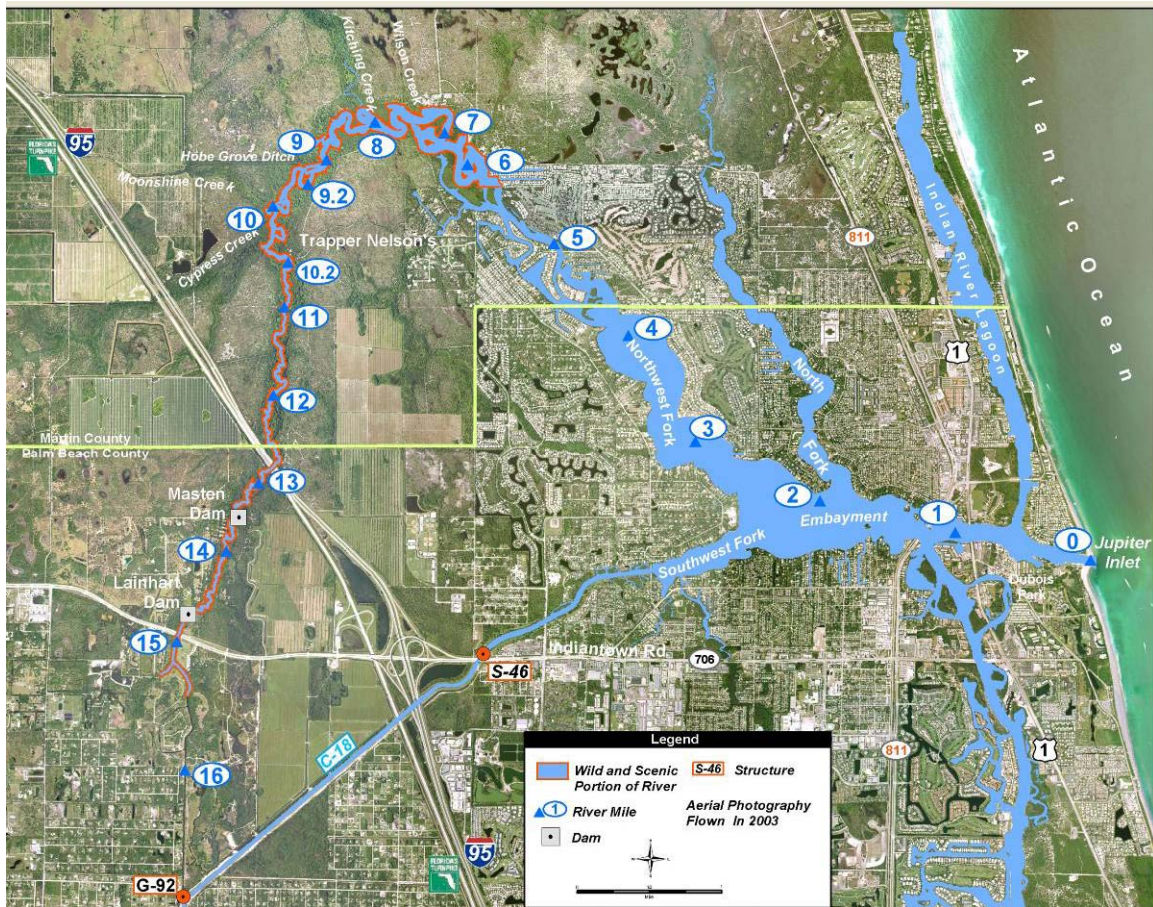
Protection of this resource requires reducing or reversing the current condition of saltwater intrusion and the subsequent transition from cypress to mangrove within the upstream freshwater portion of the Northwest Fork. It is equally important to maintain the freshwater communities in the upper reaches of the Northwest Fork for the protection of existing populations and distribution of wildlife (e.g. fishes, alligators, turtles and otters).

## GENERAL DESCRIPTION AND GEOGRAPHIC LOCATION

The Loxahatchee River and Estuary are located along the Lower East Coast of Florida. This watershed drains an area of approximately 210 square miles within northern Palm Beach and southern Martin Counties and connects to the Atlantic Ocean via the Jupiter Inlet, in Jupiter, Florida. Just west of the inlet, the river opens into a central embayment area, which is formed at the confluence of three major tributaries – the Northwest Fork, the North Fork and the Southwest Fork (**Figure 1-2**).

The Northwest Fork of the Loxahatchee River originates at the G-92 Structure in northern Palm Beach County, flows north into Martin County, continues north and bends east through JDSP, then flows southeast into Palm Beach County, and enters the embayment of the Loxahatchee River.

In 1985 the Loxahatchee River National Wild and Scenic Management Plan (FDNR, 1985) established the Wild and Scenic designation of the Northwest Fork to be 7.5 miles in length, beginning at Boy Scout Dock (River Mile 6.0) and ending at Riverbend Park (RM 13.5). With measurement techniques available at the time the river was measured from Jupiter Inlet to Riverbend Park and found to be 13 miles in length. In 2003 the SFWMD used Global Positioning System (GPS) technology to map the river more accurately, delineating its numerous oxbows, twists and turns. The recalculated length of the river from Jupiter Inlet to Riverbend Park is 15 miles and the "Wild and Scenic" portion of the river has been established as 9.5 miles in length. **Table 1-1** shows landmark sites of the Northwest Fork of the Loxahatchee River with the old River Miles used in existing documents (when applicable) and the new River Miles used throughout this document. (Note: The new River Miles are also used in the MFL Rule documents, Chapter 40E-8, F.A.C.)



**Figure 1-2.** The Loxahatchee River and its Tributaries. The River Miles depicted on this map are based on the 2003 GPS and GIS analyses for the Northwest Fork.

**Table 1-1.** River Miles of the Landmark Sites on the Northwest Fork of the Loxahatchee River.

Landmark Site	Old River Miles	New River Miles
Boy Scout Dock	6.00	5.90
Kitching Creek – USGS Monitoring Station	8.02	8.13
Hobe Grove Ditch	--	9.07
USGS Monitoring Station	--	9.12
Moonshine Creek	--	10.00
Cypress Creek	10.00	10.33
Trapper Nelson's	10.80	10.50
Turnpike/I-95	--	12.76
Masten Dam	--	13.50
Lainhart Dam	12.50	14.78
Indiantown Road	12.80	14.93
Riverbend Park	13.50	15.43



## **PARTNERSHIP WITH JONATHAN DICKINSON STATE PARK AND THE FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION**

The FDEP has statutory responsibility and authority, Chapter 258.037, Florida Statutes, to “conserve these natural values for all time.” Chapter 373.016, Florida Statutes, authorizes the SFWMD to “to preserve natural resources....” Toward the development of the restoration plan for the Northwest Fork of the Loxahatchee River, the Florida Department of Environmental Protection, which includes the Florida Park Service, and Jonathan Dickinson State Park, has actively engaged in a partnership with the SFWMD to conduct research and examine technical issues surrounding restoration. Much of this plan is based on that partnership.

On April 22, 2004, a meeting attended by staff representatives from FDEP, JDSP and SFWMD was held to discuss the guiding principles for the development of a practical restoration goal and plan for the Northwest Fork of the Loxahatchee River. Those in attendance at the meeting agreed on the following principles:

- Restoration of the Northwest Fork of the Loxahatchee River will occur between River Mile 6.0 and River Mile 15.5 to the extent practicable.
- A “practical” and “achievable” restoration goal for the Northwest Fork of the Loxahatchee River will be based on best available data.
- One part of the Loxahatchee River Watershed will not be sacrificed to benefit another part of the watershed. This principle also applies to areas of the river within the “Wild and Scenic” portion of the Northwest Fork.
- The Restoration Goal and Plan for the Northwest Fork of the Loxahatchee River will balance water supply, flood protection, water quality and environmental enhancement.
- The Restoration Goal and Plan for the Northwest Fork of the Loxahatchee River will be based on a seasonal hydrograph.
- To the extent practicable, ecological benefits will be maximized system wide.
- The focus of the goal and plan will be the restoration of the Northwest Fork of the Loxahatchee River; therefore, the title of the goal and plan will reflect that emphasis.

In addition, it was agreed that the estuarine area of the Loxahatchee River, which is located from RM 2.0 to RM 6.0, will be protected or improved through reductions of high freshwater discharges, when possible, from S-46 to the Southwest Fork of the Loxahatchee River.

## **PLANS AND IMPLEMENTATION ACTIVITIES**

During the past 20 years several plans and restoration-oriented activities have been initiated to protect and restore the Loxahatchee River, especially the Northwest Fork:

### **Loxahatchee River National Wild and Scenic River Management Plan**

In May 1985, the largely pristine portion of the Northwest Fork of the Loxahatchee River was designated by the U.S. Department of the Interior for inclusion in the Federal Wild and Scenic Rivers System, following designation by the state of Florida as a Wild and Scenic River in 1983 (Chapter 83-358, Laws of Florida, approved June 1983). The Northwest Fork of the Loxahatchee River was the first river in the state of Florida to receive this designation.

An outcome of the state and federal government actions was the formation of the Loxahatchee River Management Coordinating Council. Comprised of regional, state, federal agency and local government representatives, it oversees the impacts of proposed development, tracks plans and programs in areas adjacent to the Northwest Fork and its corridor, and is responsible for the development of a management plan.

Written by the FDEP and the SFWMD, The *Loxahatchee National Wild and Scenic River Management Plan* (2000) ensures that special consideration be given to the watershed surrounding the river corridor so that it is protected to maintain natural flow conditions, good water quality and the preservation of high quality natural areas. The plan is updated every five years to track the successful accomplishments of the member agencies and local governments and to identify new projects and programs, all of which are necessary for the protection and restoration of the Northwest Fork.

### **Lower East Coast Regional Water Supply Plan**

In May 2000, the Governing Board of the South Florida Water Management District adopted the Lower East Coast Regional Water Supply Plan (LEC Plan). The purpose of the LEC Plan is to fulfill the requirements of Section 373.0361, Florida Statutes (F.S.) for regional water supply plans. Implementation of the LEC Plan will do the following:

- Create a water supply that fully meets the future (2020) needs of almost seven million people, agriculture and industries during a 1-in-10 year drought.
- Reduce the number of severe violations of Minimum Flow and Levels (MFL) criteria for the Everglades, Lake Okeechobee and the Biscayne aquifer by 2020.
- Reserve from allocations sufficient water to allow for the restoration of the Everglades and enhancement of other significant natural systems.
- Reduce the uncertainty for issuing long-term permits for water users as they invest in tomorrow's water supply infrastructure.
- Provide public forums to modernize District operational procedures and promote greater flexibility in the operation of the regional water management system.

Several LEC Plan recommendations also provide the foundation for various actions to protect and restore the Northwest Fork of the Loxahatchee River:

LEC Recommendation 3:	Northern Palm Beach County Comprehensive Water Management Plan
LEC Recommendation 21:	L-8 Project
LEC Recommendation 32:	Periodic Operational Flexibility
LEC Recommendation 34:	Water Reservations
LEC Recommendation 35:	Establish MFLs

Water Supply Plans are updated every five years, and an update to the LEC Plan is underway, with a completion date of December 2005.

### **Northern Palm Beach County Comprehensive Water Management Plan**

Initiated in 1995, the Northern Palm Beach County Comprehensive Water Management Plan (Northern Plan) was accepted by the SFWMD Governing Board in May 2002 (SFWMD 2002a).

The sub-regional Northern Plan focuses on the southern L-8 Basin, the City of West Palm Beach Water Catchment Area (WCA-1) or Grassy Waters Preserve, C-18, the Loxahatchee Slough, and the Loxahatchee River, especially the Northwest Fork. The plan projects future water supplies for urban, agricultural and environmental uses for the year 2020 and identifies projects that when built will bring supplemental water into the northern Palm Beach County area.

The Northern Plan calls for a series of system improvements to be constructed in the area of Palm Beach County north of Southern Boulevard., generally east of the L-8 Levee, and west of I-95. When all the proposed system improvements are in place, the Northern Plan will provide the projected 2020 public water supply demands of the area, hydrologic restoration of the Loxahatchee Slough, and protection of the Grassy Waters Preserve and a target base flow of 65 cubic feet per second (cfs), in the dry season, to the Northwest Fork of the Loxahatchee River, measured at the Lainhart Dam. Construction has started on several of the Northern Plan components: the Loxahatchee Slough structure (G-160) was completed in January 2004; design of the Northlake Boulevard structure (G-161) was initiated in 2004 with construction expected to be completed in 2005; and, the regional reservoir storage at the Palm Beach Aggregates site was increased to 47,000 acre feet in 2004. The Northern Plan forms the basis for the North Palm Beach County CERP Project, Part 1.

### **North Palm Beach County CERP Project – Part 1**

The overall purpose of the North Palm Beach County CERP Project – Part 1 is to:

- (1) increase water supplies to the Grassy Waters Preserve and Loxahatchee Slough;
- (2) provide flows to enhance hydroperiods in the Loxahatchee Slough;
- (3) increase base flows to the Northwest Fork of the Loxahatchee River; and
- (4) reduce high discharges to the Lake Worth Lagoon and Loxahatchee Estuary.

The North Palm Beach County CERP Project includes six individual elements including Pal-Mar and J.W. Corbett Wildlife Management Area Hydropattern Restoration, L-8 Basin Modifications, C-51 and L-8 Reservoir, Lake Worth Lagoon Restoration, C-17 Pumping and Treatment, and C-51 Pumping and Treatment. These elements have been combined into a single project to address the interdependencies and tradeoffs between the different elements and provide a more efficient and effective design of the overall project. Further details on this project are presented on the District's Website at <http://www.evergladesplan.org>.

### **Minimum Flows and Levels Rule, Chapter 40E-8, F.A.C.**

Minimum Flows and Levels criteria for the Northwest Fork of the Loxahatchee River (SFWMD, 2002b) were developed to protect the remaining floodplain swamp community and downstream estuarine resources from "significant harm." Adopted in April 2003, the minimum flow is defined as "The limit at which further withdrawals would be significantly harmful to water resources or ecology of the area..."

More specifically, the criteria for the determination of an MFL violation are as follows:

*A MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance of the minimum flow criteria occurs more than once every six years. An "exceedance" is defined as when Lainhart Dam flows to the Northwest Fork of the river decline below 35 cubic feet per second for more than 20 consecutive days within any given calendar year.*

It was recognized that upon adoption, the District would be unable to meet the MFL criteria for the Northwest Fork during dry periods. Therefore, as required by legislation, a Recovery Strategy was incorporated into the Rule, which includes the following:

1. Construction of projects which will increase flows to the Northwest Fork and which are identified in the *Lower East Coast Regional Water Supply Plan*, the North Palm Beach County CERP Project, Part 1 and the *Northern Palm Beach County Comprehensive Water Management Plan* projects,
2. In partnership with the Florida Department of Environmental Protection and Jonathan Dickinson State Park, continue the development of a practical Restoration Plan and goal for the Northwest Fork of the Loxahatchee River,
3. Adoption of an initial water Reservation for the Northwest Fork of the Loxahatchee River to protect existing water used for the protection of fish and wildlife, and subsequent reservations to protect water made available for the recovery and restoration of the Loxahatchee River through implementation of projects which will increase flows in the dry season. These water reservations are intended to prevent the future allocation to consumptive uses the freshwater intended for restoration of the Northwest Fork of the Loxahatchee River,
4. Continue to operate the G-92 structure and associated structures to provide approximately 50 cfs or more over Lainhart Dam to the Northwest Fork, when the District determines that water supplies are available, and
5. It is the intent of the District to continue the current operational protocols of the G-92 structure so as not to reduce the historical high, average and low flows as estimated over the 30-year period of rainfall record used as the basis for the MFL for the Northwest Fork of the Loxahatchee River.

## **Loxahatchee River Watershed Action Plan**

In July 1996, the Florida Department of Environmental Protection organized the Loxahatchee River Watershed Planning Committee with representatives from various state, local and federal agencies. A Loxahatchee River Watershed map was developed and through the development of the watershed boundaries, a comprehensive list of problems could be identified for each sub-basin. In addition, water quality data and other environmental information were compiled to form a realistic view of the watershed. In October 2002 the Loxahatchee River Watershed Action Plan was completed (FDEP 2002). The purpose of this plan was to identify natural resource problems within the watershed subbasins and solutions for those problems. One of the more successful results of the Loxahatchee River Watershed Action Plan is the Loxahatchee River Preservation Initiative (LRPI), which has succeeded in gaining state appropriations for projects that contribute to the restoration and protection of the Loxahatchee River and Watershed.

## **Loxahatchee River Preservation Initiative**

The Loxahatchee River Preservation Initiative (LRPI) is the outgrowth of the Loxahatchee River Watershed Action Plan. In the past, several key projects crucial to preserving the long-term health of the Loxahatchee River could not been implemented due to lack of resources and other regional priorities taking precedence. To address this problem, the LRPI was formed in 2000 with the single purpose of seeking funds for projects that would improve and protect the natural resources within the watershed. The LRPI has been successful in obtaining approximately six million dollars for projects. Urban stormwater improvements and the restoration of areas tributary to the Loxahatchee, including the estuarine portion of the river system, are projects emphasized by the LRPI.



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## **Jonathan Dickinson Park Unit Management Plan**

This plan serves as a basic statement of policy and direction of JDSP as a unit of Florida's State Park System (FDEP, 2000). It identifies the objectives, criteria and standards that guide each aspect of park administration and sets forth specific measures that will be implemented to meet management objectives. The plan is divided into three interrelated components; resource management, land use and operations. Park goals and objectives include preserving the park's natural resources, creating awareness and appreciation for the park, enhancing organized programs and increasing attendance and visitation.

The park consists of approximately 11,383 acres in Martin County and northern Palm Beach County. Within the park, 2,600 acres comprise a wilderness preserve and 2,100 acres consist of the highly endangered scrub community. Twelve natural communities occur within the unit, including six wetland communities. The park also contains part of the National Wild and Scenic Northwest Fork of the Loxahatchee River. These rare natural features create an exceptional environment for plants and wildlife including many designated species.

## **Jupiter Inlet District Management Plan for the Loxahatchee River**

This plan is intended to continue public recreational uses, improve the productivity of the river, and preserve and enhance the natural resources and multiple uses of the Loxahatchee River for which JID has authority (JID, 1993). The plan addresses the portion of the Loxahatchee River west of the F.E.C. Railroad trestle including the embayment, North Fork, Northwest Fork, Southwest Fork, C-18 Canal, and minor tributaries. Thirty prioritized options were included in the plan. One of the specific actions that have been taken is the restoration of four oxbows in the Northwest Fork to preserve natural hydrological functions.

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## **DOCUMENT STRUCTURE**

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The next section of this document is **Chapter 2, The Loxahatchee River Watershed**. This chapter describes the Loxahatchee River Watershed which includes the Loxahatchee River and its tributaries, the Loxahatchee estuary, and the surrounding land areas. The watershed is divided into 12 drainage basins based on hydrology and land use. The hydrology, water quality, and water resource utilization of the watershed are also described.

**Chapter 3, The Ecosystems of the Loxahatchee River and Estuary**, describes the floodplain and aquatic ecosystems within the Loxahatchee River. The historic and present day distributions of species in the floodplain forest communities and oligohaline, mesohaline, and polyhaline ecozones is also presented. The occurrence of endangered, threatened, or species of special concern are also described.

**Chapter 4, Valued Ecosystem Components (VECs) and Performance Measures (PMs)**, describes the Valued Ecosystem Components selected to represent the floodplain, river, and estuary ecosystems. The Performance Measures used to evaluate the success of the restoration process are also identified.

**Chapter 5, Determining Hydroperiods and Flow Requirements in the Riverine Floodplain**, describes habitat quality and floodplain hydrology evaluations.

**Chapter 6, Modeling Freshwater Inflow and Salinity in the Northwest Fork of the Loxahatchee River and Estuary**, describes the watershed hydrology and the salinity models used to predict long-term freshwater inflow and salinity. Results from the model calibration, validation, and long-term simulations are presented. The freshwater inflow and salinity relationships are summarized.

**Chapter 7, Alternative Formulation and Evaluation**, describes the alternatives formulated for modeling, the modeling results and the ecological assessment of the alternatives.

**Chapter 8, The Saltwater Barrier as a Restoration Opportunity**, describes the 3-D salinity model used, the preliminary modeling study of salinity management using different types of salinity barriers, and the ecological considerations associated with saltwater barriers.

**Chapter 9, The Ecosystem Monitoring Plan**, describes vegetation and hydroperiod monitoring in the freshwater floodplain, vegetation and salinity monitoring in the tidal floodplain, benthos/snook monitoring in the oligohaline ecozone, oyster monitoring in the mesohaline ecozone, and seagrass monitoring in the polyhaline ecozone.

**Chapter 10, Conclusions**, summarizes the restoration alternatives for the Northwest Fork of the Loxahatchee River. The plan will recommend a practical approach to restoring appropriate dry season/wet season flows to the Loxahatchee River Watershed.

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## CONCLUSIONS

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In conclusion, the overall purpose of the Restoration Plan for the Northwest Fork of the Loxahatchee River is to establish a combination of flows and other water management practices that will restore the ecological health of the Northwest Fork of the Loxahatchee River by a managed dry season/wet season hydrologic flow pattern that will:

- Maintain or improve the hydroperiod of the riverine floodplain,
- Increase the growth and recruitment of desired freshwater vegetation and control the expansion of mangroves and exotic species in the tidally influenced floodplain, and
- Sustain or improve the habitats of oligohaline, mesohaline and polyhaline biota in the Northwest Fork, Embayment Area and Estuary.

The improved wet season/dry season flows to the Northwest Fork from its tributaries and other dry season measures are intended to protect the freshwater floodplain and improve the quality of the tidally influenced portion of the floodplain. This will maintain and protect vegetation, fish and wildlife values within the constraints of the influence of the Jupiter Inlet, sea level rise, and existing levels of flood control, C-18, G-92 and S-46. Current levels of navigation and recreation on the Northwest Fork of the Loxahatchee River will be maintained.

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## Chapter 2:

# The Loxahatchee River Watershed

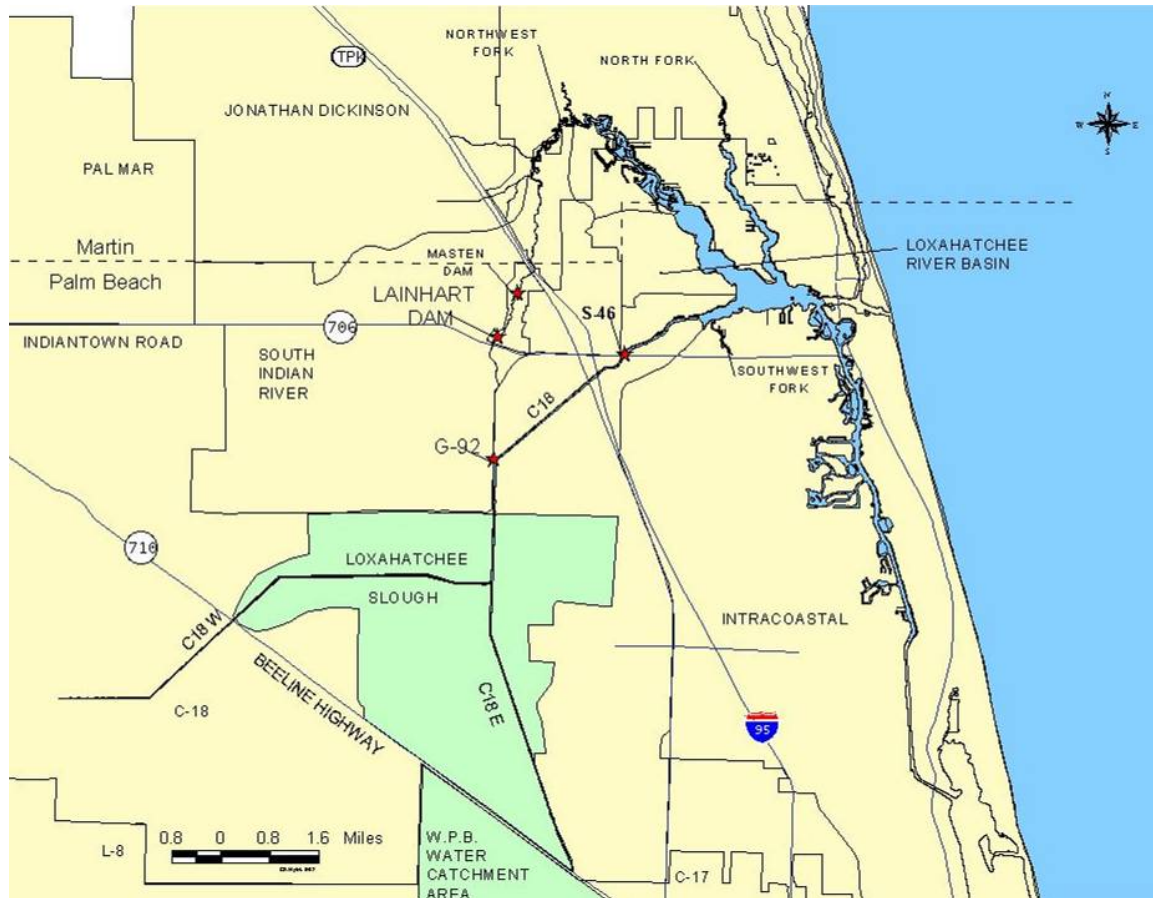
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### WATERSHED DESCRIPTION

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The Loxahatchee River Watershed is located within northern Palm Beach and southern Martin Counties and currently drains an area of approximately 240 square miles. Much of the watershed remains as undeveloped sloughs and wetlands. In the upper portion of the watershed, nearly half of the drainage basin is comprised of wetlands. Agriculture and forested uplands in the northern area of the basin comprise one quarter of the watershed. The remaining quarter of the watershed consists of developed urban areas.

The current headwaters of the Wild and Scenic portion of the Northwest Fork of the Loxahatchee River begin in the Hungryland Slough and Loxahatchee Slough. From the Loxahatchee Slough, water flows north in the C-18 canal, through the G-92 structure, over the Lainhart Dam into the natural river stream of the Northwest Fork. It enters Martin County north of Indiantown Road, (S.R. 706), then enters JDSP and continues along a northerly course, and then bends east and continues southeast through to the embayment of the Loxahatchee River. Although the majority of the water that feeds the Northwest Fork comes from northern Palm Beach County, water also flows to the Northwest Fork from southern Martin County, through Cypress Creek, Hobe Grove Ditch, Wilson Creek, Moonshine Creek and Kitching Creek. The North Fork headwaters are defined by the Atlantic Coastal Ridge in eastern Martin County and flow south-southeast into the embayment. In 1957 the Southwest Fork was channelized to form the C-18 canal to move water flows to the northeast, providing flood control to northern Palm Beach County. The Loxahatchee Estuary's embayment is located at the center of three major tributaries- the Northwest Fork, the North Fork and the Southwest Fork (**Figure 2-1**).



**Figure 2-1.** Location of the Loxahatchee River, Major Tributaries, Natural Areas, and Water Control Structures in the Watershed.

The Loxahatchee River Watershed contains a number of natural areas that are essentially intact and publicly owned. These areas include the J.W. Corbett Wildlife Management Area, JDSP, Hungryland Slough Natural Area, Grassy Waters Preserve, Loxahatchee Slough, Hobe Sound National Wildlife Refuge, Juno Hills Natural Area, Jupiter Ridge Natural Area, Pal-Mar, Cypress Creek and the Atlantic Coastal Ridge. These natural areas contain pinelands, sand pine scrub, xeric oak scrub, hardwood hammocks, freshwater marshes, wet prairies, cypress swamps, mangrove swamps, ponds, sloughs, river and streams, seagrass and oyster beds, and coastal dunes (Treasure Coast Regional Planning Council, 1999). These natural areas support diverse biological communities which contain many protected species (FDEP, 2002).

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## DRAINAGE BASINS

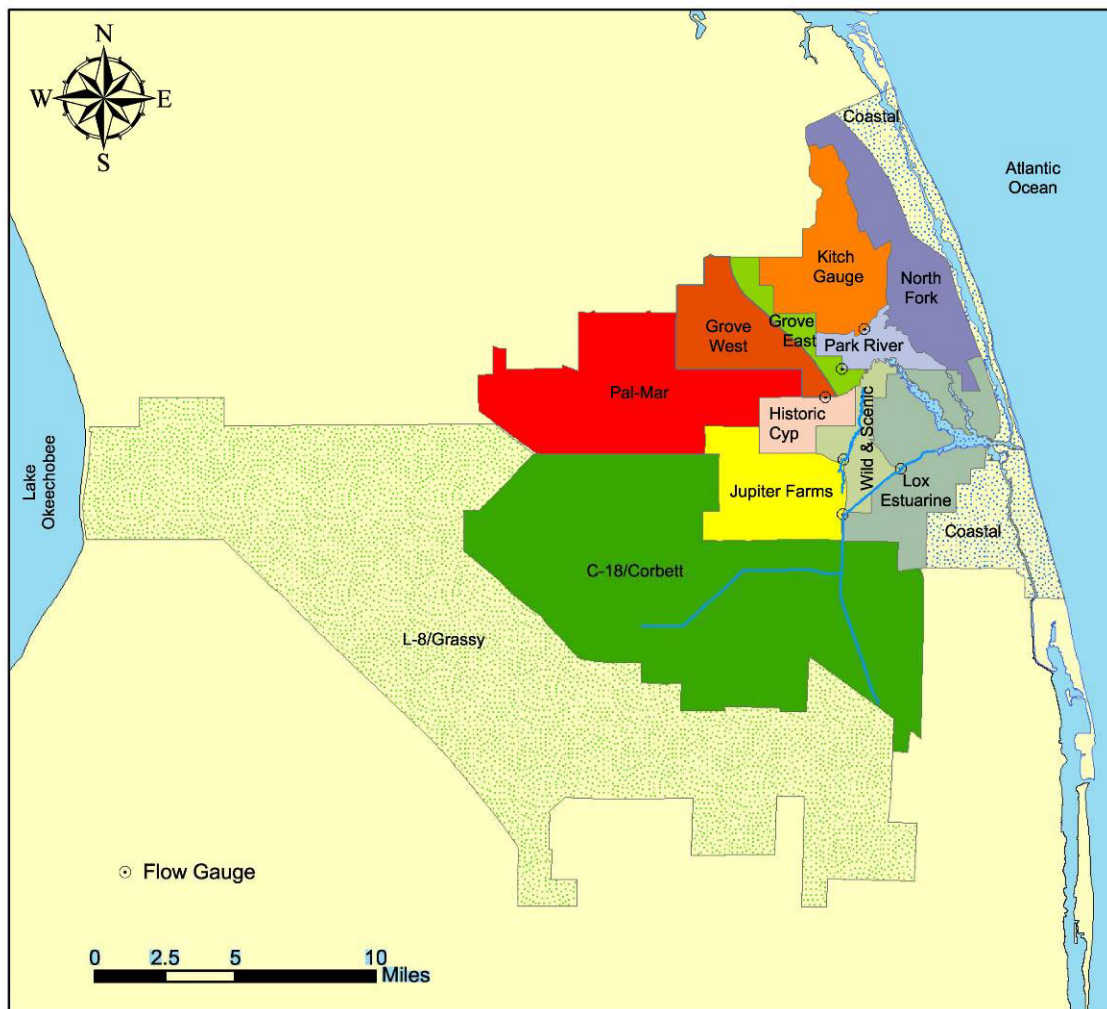
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Some of the major tributaries of the Loxahatchee River Watershed, such as the North Fork, the Northwest Fork and Kitching Creek, exist today largely within their historic banks. Other tributaries, such as the Southwest Fork, Limestone Creek and parts of Cypress Creek, have been altered over time.

The watershed drainage patterns have been significantly altered with the building of roads (e.g., S.R. 710, I-95, and Florida Turnpike), construction of the C-18 and other associated water control structures, and the development of an extensive secondary canal network. Canals were

designed to provide drainage and flood protection for agricultural and urban development and the conveyance of water for potable use and irrigation. Over time, drainage and development in the watershed have lowered ground water levels and altered natural flow regimes and drainage patterns.

For this plan the Loxahatchee River Watershed has been delineated into 12 drainage basins. These delineations were based first on the location of historic flow gauges in the watershed. Other information sources considered in the delineation included hydrology, land use, topography, permit information, detailed aerial photography, Kitching Creek Water Quality Improvement Project (Earth Tech, 1999), Pal-Mar/Cypress Creek and the Groves Basin Study (Tomasello Consulting, 2003), Loxahatchee Watershed Action Plan (FDEP, 2002), and field observations. These 12 basins represent the same areas as the 7 sub-basins described in the Loxahatchee River Watershed Action Plan (FDEP, 2002); four of the FDEP sub-basins have been subdivided into separate basins to reflect the specific needs of this plan. The basins vary in size from 5 to 100 square miles, and they provide flow to the three forks of the Loxahatchee River (**Figure 2-2**).



**Figure 2-2.** Major Drainage Basins in the Loxahatchee River Watershed.



The 1995 Land Use for these basins has been modified to include changes in the developed areas for the year 2000. For purposes of this plan, the 133 land use codes were reduced to six land use categories; Citrus & Vegetables, Forest, Marsh Wetland, Other Wetland, Urban, and Other Land. **Table 2-1** shows the breakdown of land use by Basin for the Loxahatchee River Watershed.

**Table 2-1.** Loxahatchee River Watershed 1995 Land Use By Basin - Developed Areas Updated for the Year 2000 (Acres/Square Miles).

Basin	Land Use (acres)						Total Area by Basin	
	Citrus & Vegetables	Forest	Marsh Wetland	Other Wetland	Urban	Other Land	Acres	Square Miles
1. Kitch Gauge	16	876	4,954	1,010	309	3,177	10,342	16.2
2. North Fork	0	95	8,238	735	1,774	156	10,999	17.2
3. Park River	14	60	2,483	47	31	408	3,044	4.8
4. Lox Estuarine	591	305	1,155	617	10,536	34	13,237	20.7
5. C-18/Corbett	1,821	822	43,591	4,749	9,199	3,312	63,494	99.5
6. Historic Cypress Creek	340	12	2,993	132	85	20	3,581	5.6
7. Pal-Mar	266	88	19,477	555	1,672	605	22,663	35.4
8. Grove West	4,107	168	2,878	86	54	906	8,199	12.8
9. Grove East	1,709	143	397	105	309	345	3,010	4.7
10. Jupiter Farms	8	89	494	168	9,359	128	10,246	16.0
11. Wild & Scenic	752	142	2,562	220	278	392	4,345	6.8
12. Coastal	0	2,190	2,212	2,180	8,899	391	15,872	24.9
Total Area by Land Use	Acres	9,624	4,990	91,434	10,603	42,505	9,874	169,031
	Square Miles	15.1	7.8	143.3	16.6	66.6	15.5	264.9

Blue shaded rows are watershed basins that discharge into the Northwest Fork of the Loxahatchee River.

**Basin 1: Kitch Gauge.** This basin contains the 16.2-square mile area that contributes water to the USGS Kitching Creek flow gauge in Jonathan Dickinson State Park. Almost 50% of this basin, 4,654 acres, is characterized as marsh wetland. Downstream of this basin Kitching Creek discharges into the Northwest Fork near River Mile 8.2.

**Basin 2: North Fork.** This basin contains the 17.2-square mile area that contributes water to the North Fork of the Loxahatchee River. Approximately 75% of this basin (8,238 acres) is marsh wetland. The flow from this basin is not gauged.

**Basin 3: Park River.** This basin contains the 4.8-square mile area that drains to the Northwest Fork of the Loxahatchee River. It includes the portion of land draining to Kitching Creek downstream of the gauge and some smaller tributaries such as Wilson Creek and the creek flowing through the Boy Scout Camp. Approximately 82% (2,483 acres) of this basin is marsh wetland. The flow from this basin is not gauged.

**Basin 4: Lox Estuarine.** This central drainage basin is 20.7-square miles in area and is highly developed with urban land uses that contribute significant runoff to the embayment of the Loxahatchee River. Consisting of 20.7 square miles of the watershed, this basin provides aquatic recreational opportunities that sometimes exceed the river's carrying capacity on weekends and holidays. Runoff and groundwater from this basin discharge to brackish waters of

the estuary. Approximately 80% (10,536 acres) of this basin is urban. The flow from this basin is not gauged.

**Basin 5: C-18/Corbett.** With 100 square miles, this is the largest basin in the Loxahatchee River Watershed. Much of the land in this basin encompasses the southwestern portion of the watershed, and is publicly owned and protected. This basin includes the remnants of the Hungryland and Loxahatchee Sloughs, which historically fed the Northwest Fork of the Loxahatchee River. At one time, the Loxahatchee Slough extended south into what is now known as the Grassy Waters Preserve (West Palm Beach Water Catchment Area), which is the source of drinking water for the City of West Palm Beach. Water from this basin discharges to the C-18 Canal, and is either discharged to the Southwest Fork of the Loxahatchee River through the S-46 structure or directed through the G-92 structure to the upper end of Northwest Fork of the Loxahatchee River. Approximately 69% (43,591 acres) of this basin is marsh wetland. Flow gauges are located at the G-92 and the S-46 structures.

**Basin 6: Historic Cypress Creek.** Cypress Creek is a 5.6-square mile basin that drains to Cypress Creek just downstream of the Cypress Creek flow gauge. The majority of this basin has recently been purchased by state and local governments for restoration and preservation. Water from this basin flows into Cypress Creek and discharges at the upper end of the Northwest Fork near River Mile 10.3. Approximately 84% (2,993 acres) of this basin is marsh wetland. The flow from this basin is not gauged.

**Basin 7: Pal-Mar.** Pal-Mar is a large 35.4-square mile basin. It drains a sizable wetland located along the western edge of the watershed and is one of the major tributaries to the Northwest Fork of the Loxahatchee River. Most of these wetlands remain intact; however, the eastern flow ways leading to Cypress Creek have been disturbed by rural development. Approximately 86% (19,477 acres) of this basin is marsh wetland. Water from this basin flows into Cypress Creek upstream of the Cypress Creek flow gauge and discharges at the upper end of the Northwest Fork near River Mile 10.3.

**Basin 8: Grove West.** The predominant land use in this 12.8-square mile basin is citrus. Although the hydrology in this basin was altered to support agriculture, wildlife utilization is good and the land provides a valuable greenway link between large natural areas within the watershed. Approximately 50% (4,107 acres) of this basin is used for vegetables and citrus. Water from this basin flows into Cypress Creek upstream of the Cypress Creek flow gauge and discharges at the upper end of the Northwest Fork.

**Basin 9: Grove East.** The predominant land use in this 4.7-square mile basin is citrus. Although the hydrology in this basin was altered to support agriculture, wildlife utilization is good and the land provides a valuable greenway link between large natural areas within the watershed. Approximately 57% (1,709 acres) of this basin is used for vegetables and citrus. Water from this basin flows into Hobe Grove Ditch (RM 9.07) and Moonshine Creek (RM 10.0), both of which discharge into the Northwest Fork near River Mile 9.0.

**Basin 10: Jupiter Farms.** This basin is 16.0 square miles and supports substantial rural residential development known as Jupiter Farms. The South Indian River Water Control District (SIRWCD) manages a stormwater management system of canals to serve this area. Water quality and saltwater intrusion in the Northwest Fork are concerns in this basin (FDEP, 2002). Water from this basin discharges into the SIRWCD C-14 canal which flows over Lainhart Dam feeding the upper end of the Northwest Fork. The C-18 canal is connected to this basin by the G-92 structure, which also provides periodic flows of water over the Lainhart Dam from the C-18 Canal. Approximately 91% (9,359 acres) of this basin is urban land. There is a flow gauge at both G-92 and Lainhart Dam.

**Basin 11: Wild and Scenic.** This basin contains the “Wild and Scenic” Northwest Fork of the Loxahatchee River and the northern portion of Riverbend Park. Approximately 59% of the 6.8-square mile area (2,562 acres) is marsh wetland. The flow from this basin is not gauged.

**Basin 12: Coastal.** The coastal basin contains the 34-square mile area that drains to the Atlantic Ocean or the Intracoastal Waterway (ICW) and out the Jupiter Inlet. This basin has been developed for maximum urban residential, commercial and recreational use. Very few small and isolated natural areas remain. Most of the surface water and ground water from this basin discharge to marine waters rather than toward the freshwater portion of the Northwest Fork. The flow from this basin is not gauged.

**Adjacent Basin: L-8/Grassy.** This 192.5-square mile basin is not considered part of the Loxahatchee River Watershed. However, this basin has several outflow locations, one of which is to the C-18/Corbett Basin. Thus, the inter-basin transfers of waters from Grassy Waters to the C-18 Canal are considered in this plan. There are no flow gauges at this inter-basin location.

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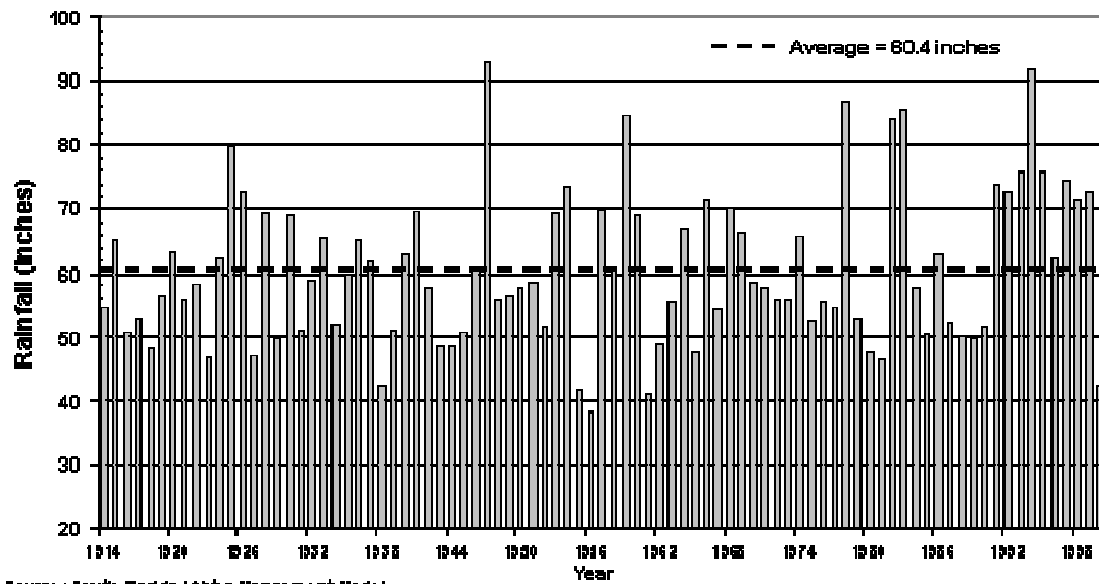
## WATERSHED HYDROLOGY

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### CLIMATE, RAINFALL AND SEASONAL WEATHER PATTERNS

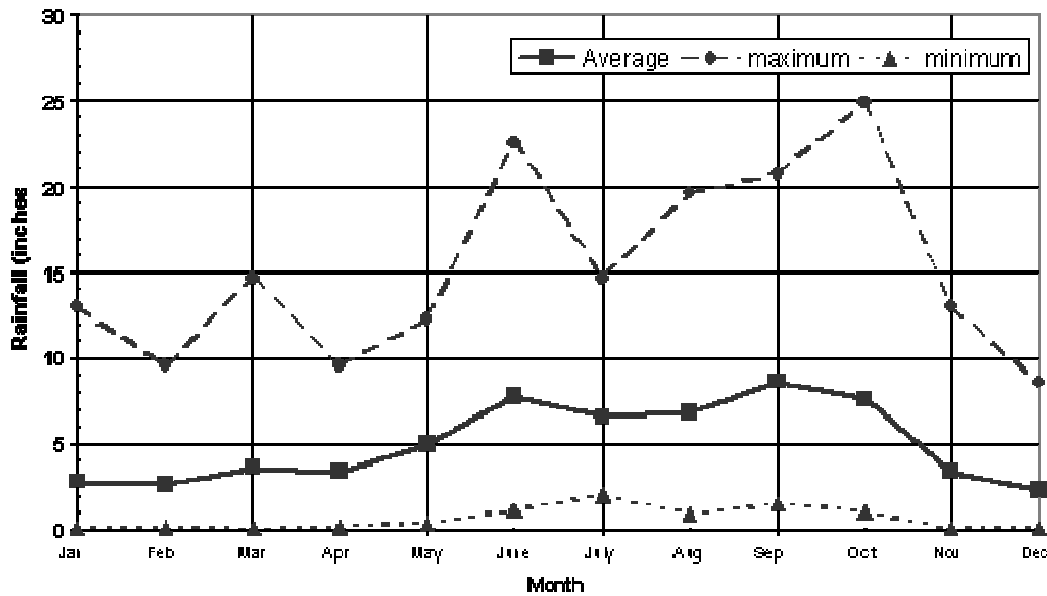
The subtropical regional climate for the area has daily temperatures ranging from an average of 82°F in summer (May-October) to 66°F in winter (November-April) with an annual temperature of 75°F (Breedlove Associates, Inc.1982). Prevailing marine east/southeast winds with an average velocity of approximately 10 miles per hour keeps the air within the watershed area moist and unstable, leading to frequent rain showers of short duration.

Annual rainfall amounts received within northern Palm Beach and southern Martin Counties are summarized in **Figure 2-3** and represent the years from 1914-2000 (data from South Florida Water Management Model, version 9.7). Mean annual rainfall for the entire 86-year period of record was 60.4 inches with a median of 57.7 inches. The maximum annual rainfalls recorded were 92.9 inches in 1947 and 91.6 inches in 1994. Minimum rainfall values occurred in 1956 (38.4 inches) and 1961 (41 inches). Review of the distribution of annual rainfall data over time showed that a variance of about 10 percent of the mean ( $\pm 6$  inches) occurs about once every 3 years on average. Extreme dry and wet periods can be defined as a variance of more than 20 percent of the mean ( $\pm 12$  inches). Based on this definition, the long-term record shows that an extreme dry period occurs within the basin once every 8.6 years, while extreme wet periods occur about once every 5.7 years.



**Figure 2-3.** Long-Term Annual Rainfall for Northern Palm Beach and Southern Martin Counties (1914–2000) Based on the SFWMM.

The average, minimum, and maximum monthly rainfall amounts for northern Palm Beach and southern Martin Counties for 1914-2000 are summarized in **Figure 2-4**. On average, the highest rainfall of 8.7 inches per month occurs during September, while minimum average values range from 2.3 – 2.8 inches per month for December, January and February. May and November are transitional months and sometimes represent key months for prolonging or reducing a drought or flood condition. Dent (1977a) reported that since the early 1960s, about two-thirds of this precipitation (40.63 inches) occurs during the wet season (June–November), while the remaining one-third (20.42 inches) falls during the dry season (December–May). During the winter and early spring, some years have long periods of little or no rainfall, resulting in a regional drought condition. In contrast, tropical storms or hurricanes over the area can produce as much as 6 to 10 inches of rainfall in one day in the wet season.



Source: Model results from the South Florida Water Management Model (SFWMM)

**Figure 2-4.** Average, Minimum and Maximum Rainfall Values, by Month, for Northern Palm Beach and Southern Martin Counties (1914–2000) Based on SFWMM.

## TRIBUTARY AND CANAL SYSTEM

The Northwest Fork once drained the majority of the Loxahatchee Basin. The headwaters to the river began in the marshes of the Loxahatchee and Hungryland Sloughs, and in what is now Grassy Waters Preserve (**Figure 2-1**). The Loxahatchee Slough once extended south to the Grassy Waters Preserve (West Palm Beach Water Catchment Area). Increased urban and agricultural development over the last 100 years has greatly altered the natural system of the Loxahatchee River watershed from what once was defined by natural landforms. Navigation, drainage and flood control activities have significantly altered the volume, timing and distribution of freshwater flow, both in quality and quantity, throughout the Loxahatchee River and Estuary system. The reduction in flow can be attributed to the diversion of the historic Northwest Fork flows by the construction of C-18 canal. This area, once drained as sheet flow across flat landscape, has become divided by canals, levees and drainage ditches. Over time these changes have lowered the water table and have allowed the land to drain much faster. Along with the stabilization of the Jupiter Inlet, reduced flows to the Northwest Fork have allowed saltwater to move further upstream.

The C-18 canal drains through a gated water control structure, S-46. In order to reduce the amount of freshwater lost to tide, the operation of S-46 was modified in 1981 to provide water storage in the canal. The automated operation of the gates at S-46 maintains an optimum headwater elevation of 14.8 feet when sufficient water is available. When C-18 canal levels are more than 15 feet above mean sea level, water is released through S-46 to the Southwest Fork. The S-46 structure also prevents saltwater from moving upstream into the C-18/Corbett Basin.

Water is conveyed from the Loxahatchee Slough north through the C-18 canal, diverted through the G-92 structure to the SIRWCD C-14 canal, where it meets the Northwest Fork and then flows over the Lainhart and Masten Dams. The G-92 structure was installed to direct flow into the Northwest Fork from C-18. Updated in 1987 to a gated control structure, G-92 is capable

of providing 400 cfs of water to the Northwest Fork. Operation of this structure is by remote telemetry under a Consent Agreement between the SFWMD and the South Indian River Water Control District (1989; **Appendix G**) to allow conveyance of environmental flows to the Northwest Fork. This Consent Agreement requires the SFWMD to operate the G-92 structure to provide 50 cfs of flow, when available to the Northwest Fork. During extremely wet storm events, G-92 moves excess water into the C-18 for flood protection.

The Lainhart Dam, built in the 1930s, along with the Masten Dam, have slowed the flow of freshwater through the upper Northwest Fork. Today, the reconstructed Lainhart Dam provides close to 50 percent of the total discharge to the Northwest Fork. In some months, discharge can be as low as 28 percent or as high as 72 percent.

At RM 10.3, Cypress Creek provides a considerable volume of surface water to the Northwest Fork especially during low flow periods. Located downstream from the Trapper Nelson site (RM 10.5) in JDSP, this tributary enters the river from the west providing on average 26-32 percent of the total flow to the Northwest Fork. Flows from this creek are controlled by a structure operated by Hobe St. Lucie Water Control District, which is a local drainage district.

The Hobe Grove Ditch drains to the east of the Florida Turnpike entering the Northwest Fork at River Mile 9.07. Discharges from this ditch average approximately five percent of the freshwater into the Northwest Fork. A water control structure at this ditch is operated by the Hobe St. Lucie Water Control District.

At RM 8.13, Kitching Creek contributes 11-13 percent of all the flows to the Northwest Fork. This creek is located in an area made up of ponds and marshes that includes properties just north of and within JDSP. Water retention in this area is high due to the fact that it is the least developed of all the major tributaries contributing to the Northwest Fork.

Direct rainfall, surface water flow and groundwater seepage are the three sources from which water enters the Loxahatchee River. Rainfall is also the major source of freshwater that fills the surface water bodies and channels in addition to recharging the shallow aquifers. Because of the network of canals and ditches and the lack of storage, most of the rainfall is discharged as stormwater runoff during the rainy season. Therefore, less water is available during the dry season to maintain sufficient flows to the Northwest Fork.

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## WATER QUALITY

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### WATER QUALITY MONITORING ACTIVITIES

During the last 25 years, the surface waters of the Jupiter Inlet-Loxahatchee River have been extensively sampled and analyzed for water quality. In the 1970s and 1980s, the United States Geological Survey (USGS) provided a water quality monitoring presence from the federal perspective. The FDEP and the SFWMD each sponsored monitoring programs from the state and regional perspective. On the county and local level, the Palm Beach County Health Department, the Palm Beach County Department of Environmental Resources Management and the Loxahatchee River District (LRD) also monitored water quality. Water quality as well as water quantity improvements are a major concern for Loxahatchee River watershed. The LRD continues bi-monthly water quality monitoring to document the status and progress of improved water quality conditions.

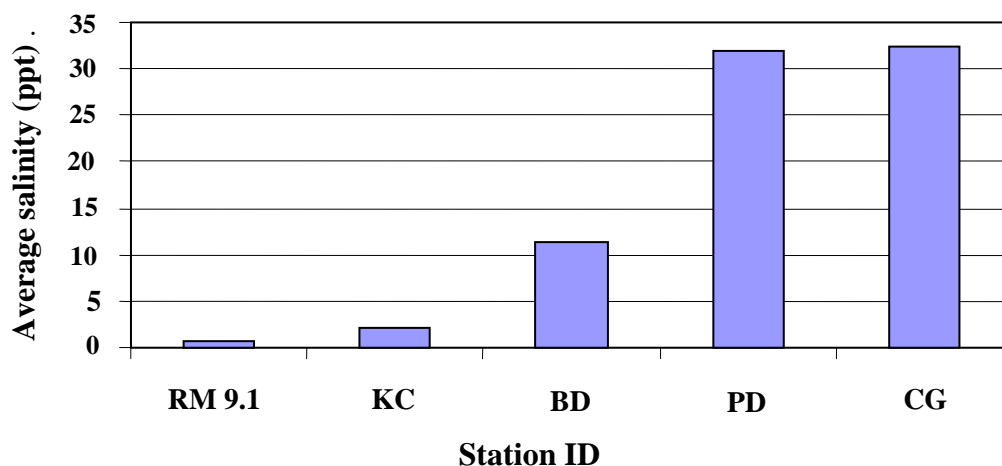
Since 1992, the LRD has assumed responsibility for comprehensive monitoring in the river and now monitors 35 stations every other month. Of the 35 sites, 18 are located in the Northwest Fork. In the early 1990s, the LRD, in cooperation with a technical advisory committee comprised

of representatives of the other monitoring efforts, organized the existing water quality data by collecting and screening all previously collected data. A common database was established and the data presented in a format which could be indexed, composited and compared to Florida State values and standards. The resultant information was further organized by dividing the Loxahatchee River into 29 sample locations in four ecological segments (Marine, Estuarine, Wild and Scenic, and Freshwater Tributaries). Five time-groupings covering 22 specific water quality parameters were developed. This procedure was initiated in 1995 and the water quality data are updated every six months.

## SALINITY AND TIDE

The Loxahatchee Estuary was formed several thousands years ago when sea water flooded the embayment area as a result of sea level rise. Now the saltwater front has reached the upper Northwest Fork of the Loxahatchee River. The mean tidal range in the estuary is approximately 2 feet; the estimated mean tidal prism at A1A Bridge is approximately 3226 acre-feet. (McPherson et al., 1982).

Salinity distribution in the Loxahatchee Estuary is characterized by longitudinal and vertical salinity gradients that change daily with tides and seasonally with the quantity of the freshwater inflow. A network of tidal and salinity monitoring stations has been deployed in the estuary since October 2002. **Figure 2-5** shows the annual average salinity over the period from November 1, 2003 to October 31, 2004.



**Figure 2-5.** Average Annual Salinity Gradient in the Loxahatchee Estuary.

The salinity measurements were taken at five stations in the Northwest Fork and the estuary: RM 9.1; RM 8.1 (KC) the confluence of the Northwest Fork and Kitching Creek; RM 5.9 (BD) the Boy Scout Camp Dock; RM 1.8 (PD) Pompano Drive on the south shore of the embayment area; and RM 0.7 (CG) the Coast Guard station near the Jupiter Inlet. **Table 2-2** compares the monthly average salinity in April 2004 with the annual average salinity of 2004. April was a relatively dry month for the year 2004 so there was a reduced amount of freshwater entering the estuary which resulted in a higher salinity than the annual average salinity. This difference was the most apparent at the Boy Scout Camp station near River Mile 5.9.



The upstream migration of salt water into the historic freshwater reaches of the Loxahatchee River is the likely cause of the altered floodplain bald cypress forest community along the Northwest Fork and some of its tributaries (McPherson, Sabanskas, & Long, 1982). A hydrodynamic/salinity model was developed to study the influence of freshwater input on the salinity conditions in estuary. Both the field data and model simulations indicate a strong correlation between freshwater inflow and the salinity regime in the estuary.

**Table 2-2.** Comparison of Dry Season Salinity With Annual Average Salinity (ppt).

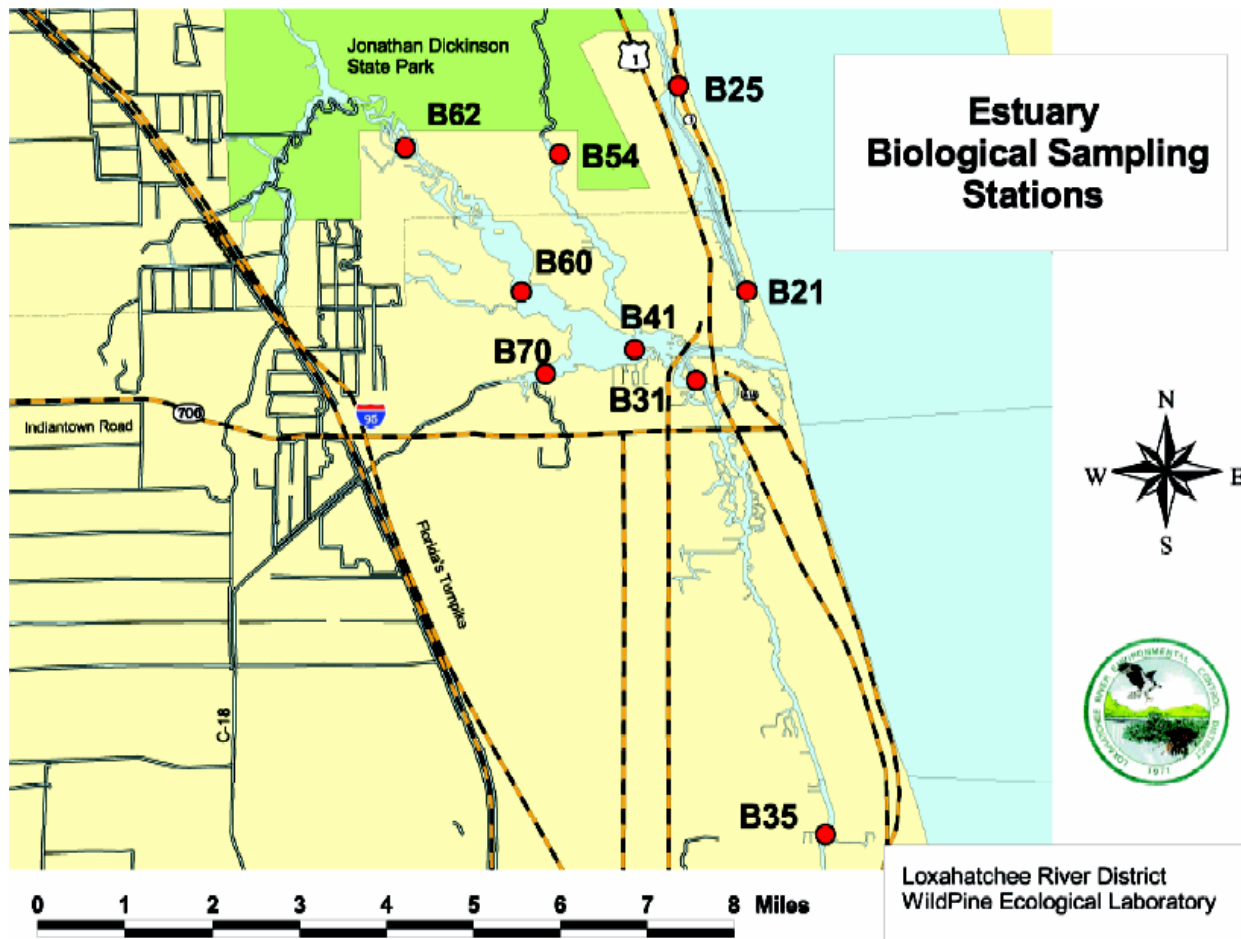
Station ID	RM 9.1	KC	BD	PD	CG
Dry season salinity (ppt)	1.43	5.13	18.26	34.87	34.96
Annual average salinity (ppt)	0.61	2.17	11.34	32.04	32.36

The salinity values in **Table 2-2** are annual average or seasonal average salinities. The actual salinity in the Loxahatchee River varies greatly in response to the amount of freshwater flow and tides. The salinity changes hourly in response to tides, however, it can take days to respond to changes in freshwater flow from the tributaries.

## NUTRIENTS

Large amounts of nutrients are typically present in any estuary system. Nutrient sources can include groundwater, runoff from fertilizers, other chemicals entering the system through precipitation and rainfall, and the normal breakdown of soil and water. In addition, with the tidal transition from freshwater to saltwater there is high organism mortality which contributes to the rapid cycling of nutrients and high productivity in the estuary (SFWMD, 2002).

The Florida Water Quality Index (FWQI), a composite of clarity, oxygen, organic demand, nutrients, bacteria and biological integrity, is used to compare sampling sites statewide giving values ranging from 0-90. Lower values indicate better water quality conditions (Dent, 1998). The LRD sampled two stations in the NW Fork twice a year between 1992 and 1997. Station #60 is located 3.2 miles upstream of the Jupiter Inlet and Station #62, 2.1 miles further upstream from Station #60 (**Figure 2-6**). The FWQI values for these two stations averaged 37 and 41, respectively. These values indicated a water quality rating of good (Dent, 1998).

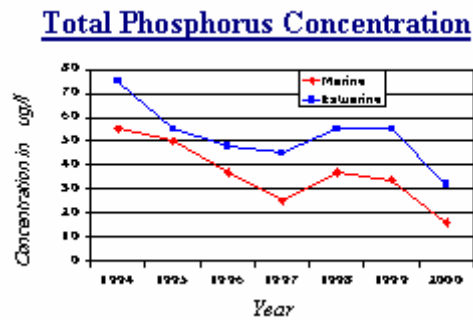


**Figure 2-6.** Loxahatchee River District Water Quality Sampling Sites.

A 24-year average (1970-1993) FWQI for the freshwater tributaries flowing into the Wild and Scenic corridor has remained fair at 48; however, the index improved to good with a 43 by the mid 1980s. This improvement was most likely due to an increase in flows to the NW Fork from the C-18 canal, a Class I waterbody that is rated superior for the FWQI. This statewide water quality index considers a 45 or less to be a good rating and ranges above 45 are fair. Florida stream sites on average have a rating of 43 (FDEP, 2000).

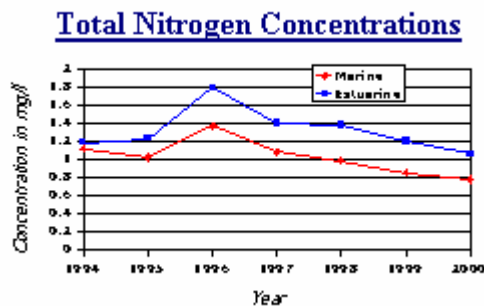
The Florida Trophic State Index (TSI) developed by the FDEP in the 1980s provides a way of classifying the trophic state of lakes and estuaries in Florida. The index categorizes the trophic status (oligotrophic, mesotrophic or eutrophic) based on the following parameters; nitrogen, phosphorus, chlorophyll and clarity as measured by secchi disc depth. The scale ranges from 0-100 with values of less than 50 receiving a good rating (oligotrophic), values ranging from 50 to less than 60 receive a fair rating (mesotrophic) and values of 60 or above receive a poor rating (eutrophic). For the 7-year period from 1994–2000 the TSI index rating in the NW Fork at Station #60 was 46 (good) and for Station #62 was 49 (good) (Dent, 2001).

The annual average total phosphorus (TP) concentrations for the period 1994–2000 for seven estuarine stations ranged between 31 to 75 ppb (see **Figure 2-7**). This range of values is considered high. These concentrations were similar to concentrations observed prior to 1990. These surface water concentrations were much lower than the statewide average of 80 ppb for the 1990 to 1998 period. (Dent, 2001)



**Figure 2-7.** 1994-2000 Total Phosphorus Concentrations (Dent, 2001).

The total nitrogen (TN) annual mean concentrations for these same seven stations were 1.0 to 1.8 mg/L (**Figure 2-8**). The trend for this seven-year period showed an improvement from 1994-2000. Historically, TN values in the 1970s averaged 0.7 mg/L, which was significantly lower than the 1994-2000 values. In general, the concentrations are slightly higher than the statewide average of 1.2 mg/L for TN in estuarine waters. (Dent, 2001)



**Figure 2-8.** 1994-2000 Total Nitrogen Concentrations (Dent, 2001).

## WATER QUALITY SUMMARY

Seven groups of stations have been monitored over the years within the “Wild and Scenic” portion of the Northwest Fork. Additionally, six sampling sites are located in the freshwater tributaries flowing into the Northwest Fork. In general terms, the sampling results show that the water quality of the flows from the freshwater tributaries have remained fair for the period of record between 1970 and 1993. The trend is an overall decline in the quality of the inflows from the tributaries over time. However, the water quality trend in the Northwest Fork is graded fair for the first portion of the monitoring period, and the grade improved to good in the mid-1990s.

The major reason for the improvement and apparent inconsistency with the declining quality of the input flows is believed to be the increased freshwater flows to the Northwest Fork from the C-18. The C-18 is a Class I water body and has rated superior to the other freshwater inputs and has not shown significant degradation over time.

In summary, water quality data have been compiled and analyzed by FDEP to determine current status and trends in this system. Results of this analysis indicate that water quality is generally adequate to meet the designated uses, which include the following:

- C-18, upstream of S-46 – Class I, Potable water supply
- Loxahatchee Slough, C-14 Canal, the Northwest Fork and the North Fork – Class III, Fish and wildlife habitat/natural systems
- Estuarine waters and Aquatic Preserves – Class II, shellfish harvesting

A few exceptions have been noted at some locations where these standards are not met periodically as follows:

- Low levels of dissolved oxygen occur periodically in some parts of the system.
- Total coliform concentrations exceed safe standards periodically in the Northwest Fork near JDSP, in the North Fork near the Girl Scout Camp and at Dubois Park near the Jupiter Inlet.
- Rapid changes in salinity and increased turbidity are associated with high volume releases of freshwater through the S-46 structure on the C-18 canal during and after severe storm events.
- Waters discharged from agricultural lands occasionally contain measurable quantities of pesticides and low concentrations of dissolved oxygen that may cause fish mortality.
- Low levels of dissolved oxygen occur within the North Fork, Northwest Fork, Kitching Creek, Cypress Creek, Floodplain/Jupiter Farms, Jonathan Dickinson State Park, and the C-18 water body segments.

Aside from the salinity issues, water quality issues in the Northwest Fork will be addressed through the identification of impaired water bodies and development of Total Maximum Daily Loads (TMDLs) criteria for segments of the river and its tributaries that have significant problems. Kitching Creek, Cypress, Floodplain/Jupiter Farms, and the C-18 are on the FDEP Verified List of Impaired Waterbodies for Biology and must be associated with causative pollutants, and will require further evaluation through the TMDL Program (FDEP, 2003b).

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## WATER RESOURCE UTILIZATION

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### WATER SUPPLY

Water withdrawals for public water supply and agricultural irrigation in the basin come directly from either ground water through the surficial or Floridan aquifer, and/or through surface water from lakes. Most irrigation permits with a permitted surface water source also have ground water allowance. Water withdrawals from the surficial aquifer strongly influence the water levels in the adjacent wetlands and affect the ground water discharge to the river and estuary and are therefore limited. Floridan aquifer withdrawals do not influence water flows to the river or estuary but create the need for disposal of the reverse osmosis concentrate, requiring a FDEP permit.

The land uses in the Loxahatchee River Watershed consist of about 20,000 acres of agriculture (11% of the basin), 32,000 acres (18%) urban and industrial, 120,000 acres (67%) water bodies and conservation lands, and 8,000 acres (4%) recreational. Total water use in the basin is estimated at about 100 million gallons per day (mgd), of which public water supply is 68 percent, agriculture accounts for an estimated 18 percent, and golf courses and industrial uses account for about 14 percent.

Access to fresh ground water is limited due to shallow aquifers, the saline tides coming from the inlet and the presence of several isolated wetlands to the west. The low permeable fine sand,

silt and hardpan beds slow down the vertical flow of water through the mixed layer aquifer. Rainfall provides the major source of freshwater, filling surface water bodies and channels and eventually recharging the shallow aquifer system. Water is generally found between 80 and 150 feet below the surface. Surficial aquifer wells in the watershed draw 150 to 300 gallons per minute depending on the size of the well and its location relative to the substrate.

A significant amount of water is withdrawn from the Florida Aquifer for public water supply. The SFWMD regulates all surface water or ground water withdrawals for consumptive use through permits, except for domestic uses. Consumptive use permits (CUP) are issued for public water supplies, agricultural and golf course irrigation, dewatering, and industrial withdrawals. Seawater, reclaimed water, and water used for domestic self-supply and fire-fighting are excluded from the permitting process. Permits issued have a fixed duration and applicants must reapply for renewal once they expire. To receive a CUP the applicant must demonstrate that the proposed water use is reasonable - beneficial; it will not interfere with existing legal users and is consistent with the public interest. The combined annual allocation for all water use permits within the watershed as of May 2002 was 37,672 million gallons per year which is an overall average of about 100 million gallons per day.

During drought conditions, rainfall is unavailable for irrigation and public water supplies and therefore water withdrawals usually increase. Increased withdrawals have the potential to cause significant harm to the water resources in the basin. However, during water shortages, the SFWMD restricts the consumptive use withdrawals, based on the concept of equitable distribution between users and the water resources. Under this program there are four levels or phases of water shortage restrictions that are imposed relative to the severity of the drought conditions. Golf courses that use reclaimed wastewater for irrigation are exempt from water shortage restrictions.

## **FLOOD PROTECTION**

The C-18 canal, with its many secondary and tertiary networks, is part of the regional primary drainage system of the SFWMD providing flood protection to the Loxahatchee River Watershed. The C-18 canal was constructed through the central portion of the Loxahatchee Slough in 1957 as part of the Central and Southern Florida Flood Control Project (CSFFCP) to improve drainage and provide flood protection for adjacent agriculture, residential, and industrial land as well as J.W. Corbett Wildlife Management Area.

The G-92 structure reconnects the C-18 and the Loxahatchee Slough with the Northwest Fork. As a gated control structure, G-92 can pass 400 cfs in either direction especially during storm events via remote telemetry. In addition, it is designed to convey environmental flows of 50 cfs when to the Northwest Fork when adequate water is available.

A major secondary drainage system, which is adjacent to the Northwest Fork, is operated and maintained by the South Indian River Water Control District (SIRWCD). This system lies north and west of C-18 and serves a rural-residential area known as Jupiter Farms. Seven east-west collector canals drain this area into the C-14 canal, which then directly discharges into the Northwest Fork, just south of the Indiantown Road Bridge. A North-South canal, C-14, parallels the C-18, re-diverting water from the C-18 back to the Northwest Fork through G-92. The C-14 ends where the natural meandering pattern of the river begins in the Northwest Fork. In 2004, sheet pile weirs, each with operable gates, were constructed at the east ends of Canals 2, 3, 4 and 5 and C-14 Canal north of its intersection with Canal 6. These structures will improve groundwater recharge in this area, reduce overdrainage in the dry season, and improve the quality of water discharged into the Northwest Fork.

The primary flood control facility for the Loxahatchee River Watershed, water control structure S-46, is a reinforced concrete, gated spillway located on the C-18 canal with discharge by three stem-operated, vertical lift gates, which are remotely controlled. S-46 also supports water level gauges upstream and downstream by remote digital recorders, a gate position recorder and a rain gauge with a remote digital recorder. Gates are automatically controlled so that the operating system opens or closes the gates in accordance with standard operational criteria. It is located approximately 0.5 miles east of the Florida Turnpike/Interstate-95 (I-95). It maintains optimum upstream water control stages in the C-18. The S-46 is designed to pass 50 percent of the Standard Project Flood without exceeding the upstream flood design stage; it restricts downstream flood stages and channel velocities to non-damaging levels.

The managed water levels in the river and canal systems of the Loxahatchee Watershed provide for drainage of land and some storage of water during the wet season. The C-18 also provides for adequate conveyance capacity to protect lives and property in the surrounding upland residential areas from flood damage during severe storm events. The amount of area available for storage in the C-18 basin is limited.

## **NAVIGATION AND RECREATION**

The Loxahatchee River's natural features and its proximity to the urban areas of Southeast Florida make it exceptionally well suited to provide outdoor recreation. Historically, canoeing has been the main recreational use of the Northwest Fork and its surrounding area, but other activities include kayaking, fishing, nature study, wildlife observation and motor boating. Motor boating in the Northwest Fork is effectively restricted to areas downstream from Trapper Nelson Interpretive Site because of the naturally narrow channel, numerous natural obstructions and natural shallow depth of the upper reaches.

The reaches of the Northwest Fork included in the "Wild and Scenic" designation have relatively limited public access points, the primary access point is located within JDSP at the concession store. Existing access and major facilities that support public use are clustered at each end of the "Wild and Scenic" portion of the Northwest Fork. Most existing river-related recreational uses and major facilities occur within JDSP, but in the future other facilities will be provided and managed by Palm Beach County Department of Recreation at Riverbend Park when it is opened to the public. Riverbend Park is located south of Indiantown Road and west of the C-18 canal. It comprises more than 600 acres and when open will provide a half-mile long "recreational" segment of the Northwest Fork.

## CHAPTER 3

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# Chapter 3:

## The Ecosystems of the Loxahatchee River and Estuary

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### AN OVERVIEW

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The upstream floodplains, freshwater and tidal, of the Northwest Fork and the Loxahatchee River Estuary are unique regional resources in several ways. Much of the Loxahatchee River watershed's natural areas remain intact. Within the Jonathan Dickinson State Park (JDSP) the rare biological community of coastal sand pine scrub is found. Other terrestrial habitats found within the watershed include pinelands, xeric oak scrub, hardwood hammocks, freshwater marshes, wet prairies, cypress swamps, mangrove swamps, seagrass beds, tidal flats, oyster beds and coastal dunes (Treasure Coast Regional Planning Council, 1999). There are also distinct aquatic environments within the Loxahatchee River system: the freshwater zone, the oligohaline (low salinity) zone, the mesohaline zone, and the polyhaline zone. These terrestrial and aquatic habitats support diverse biological communities including many protected species such as the manatee, an aquatic mammal which is restricted to Florida during the winter, and the four-petal pawpaw, a tree which is found only in Martin and Palm Beach counties. The Northwest Fork of the Loxahatchee River is home to one of the last vestiges of native cypress floodplain swamp within southeast Florida.

### THE NORTHWEST FORK

Some of the first changes to this natural system occurred in the 1930s when private individuals constructed the Lainhart and Masten dams on the Northwest Fork to maintain water levels in the Northwest Fork. Re-constructed in the 1980s these dams helped to maintain higher surface water levels behind the dams, especially in the dry season, thereby reducing over drainage of the area. During the 1950s, the C-18 Canal was built through the Loxahatchee Slough to provide flood protection and to redirect water to the Southwest Fork. This project greatly reduced freshwater flows to the Northwest Fork and in 1974, the North-South Canal, C-14, was built to re-direct water from the C-18 canal back into the Northwest Fork. The C-14 Canal ends where the natural meandering of river begins in the Northwest Fork. The G-92 structure was also constructed during this time allowing a flow of 50-100 cfs through the Northwest Fork at the intersection of C-18 and the Northwest Fork. Today G-92, a gated control structure now operated by remote telemetry, allows up to 400 cfs of water to flow into the Northwest Fork. In addition, a 1989 agreement between the South Indian River Water Control District, the SFWMD, and the Loxahatchee River Environmental Control District (LRD) allowed for flows through G-92 into the Northwest Fork when feasible (**Appendix G**).

Within the natural river channel, the Northwest Fork averages 3 to 6 feet deep (Chiu, 1975) with a maximum depth ranging up to 16 feet near Cypress Creek. Maximum depths further upstream (beyond RM 10.3) are generally less than 10 feet. Most of the watershed remains in a natural, undeveloped state, protected in parks or preserves or in low-intensity agricultural use leaving the water quality of the runoff good in most areas.

The estuarine portion of the Northwest Fork begins at the embayment (RM 2.5) and extends upstream approximately 2 miles to RM 4.5. From there, the estuary narrows significantly and becomes the river channel. The average width of this estuary segment is about one-half mile with a depth of 4.2 – 12.5 feet and covers 320 acres.

The Northwest Fork originally drained most of the Loxahatchee River basin and continues to provide about 65 to 67 percent of the total freshwater flow to the estuary during the wet season and 89 to 94 percent during the dry season. The brackish waters in this area are dependent upon flows and tides. Bottom salinities in the Northwest Fork remain above 25 ppt. (parts per thousand) and range from 20 to 35 ppt during typical wet season conditions. During extreme storm-related discharge events, salinities can drop below 10 ppt (Russell and McPherson, 1984). This brackish water system supports diverse communities of estuarine fish, benthic fauna and oyster populations in its upper portions and marine seagrass communities as it nears the embayment.

## THE ESTUARY

Saline waters from the Atlantic Ocean flow through the Jupiter Inlet and merge with the freshwaters flowing from the North, Northwest and Southwest Forks of the Loxahatchee River to form the Loxahatchee Estuary or Embayment. This shallow embayment has an average depth of 3.5 feet and a maximum depth of 15 feet and covers an area of 380 acres (Russell and McPherson, 1984; FDEP, 1998; Antonini et al., 1998).

Development along the east coast of Florida has changed the hydrology of the Loxahatchee River Estuary. The Jupiter Inlet once opened and closed because of natural events. During storm events the inlet was kept open due to flows from the Loxahatchee River, Lake Worth Creek and the southern part of the Indian River Lagoon. However at the turn of the century, the construction of the Intracoastal Waterway and Lake Worth Inlet and modifications to the St. Lucie Inlet diverted water flows and caused the inlet to remain closed most of the time. In 1947, the United States Army Corps of Engineers dredged the inlet, and has since kept the inlet permanently open.

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## THE FLOODPLAIN ECOSYSTEM

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In this section, we will examine the characteristics of the floodplain forest reaches and community types found on the Northwest Fork of the Loxahatchee River. River floodplains are an important part of any watershed system. They provide storage and filtration of surface water, diverse habitats for plants and animals, corridors for the movement of animals and dissemination of plants, and provide a supply of nutrients to estuarine environments (Darst et al., 2003). In Mitsch and Gosselink (1993) these riparian zones are described as “the interface between terrestrial and aquatic ecosystems.” Gregory et al. (1991) described riparian zones as ecotones that encompass distinct gradients of environmental factors, ecological processes and plant communities and are composed of mosaics of landforms, communities and environments within larger landscapes.

The floodplains of the Northwest Fork of the Loxahatchee River consist of tropical and temperate zone riparian forest. As a riparian forested wetland system, these vegetative communities vary from dry to occasionally flooded as the river and its tributaries react to local rainfall events. Hydric and mesic hammocks commonly signify a higher elevation within the floodplain topography. Riparian forests are generally referred to in the Southeastern United States as bottomland hardwood forests. They contain diverse vegetation that varies along gradients of flooding frequency. These forests are generally considered to be more productive than the

adjacent upland forests because they receive a periodic inflow of nutrients, especially when flooding is seasonal rather than continuous (Mitsch and Gosselink, 1993). Swamps are defined as woody wetlands that have standing water for most if not all of the growing season. Swamps on the floodplains of the Loxahatchee River consist primarily of bald cypress (*Taxodium distichum*), red and white mangroves (*Rhizophora mangle* and *Laguncularia racemosa*), pond apple (*Annona glabra*) and pop ash (*Fraxinus caroliniana*). The Loxahatchee River contains some of the last pristine subtropical cypress swamps in Southeast Florida.

## HISTORICAL FLOODPLAIN STUDIES

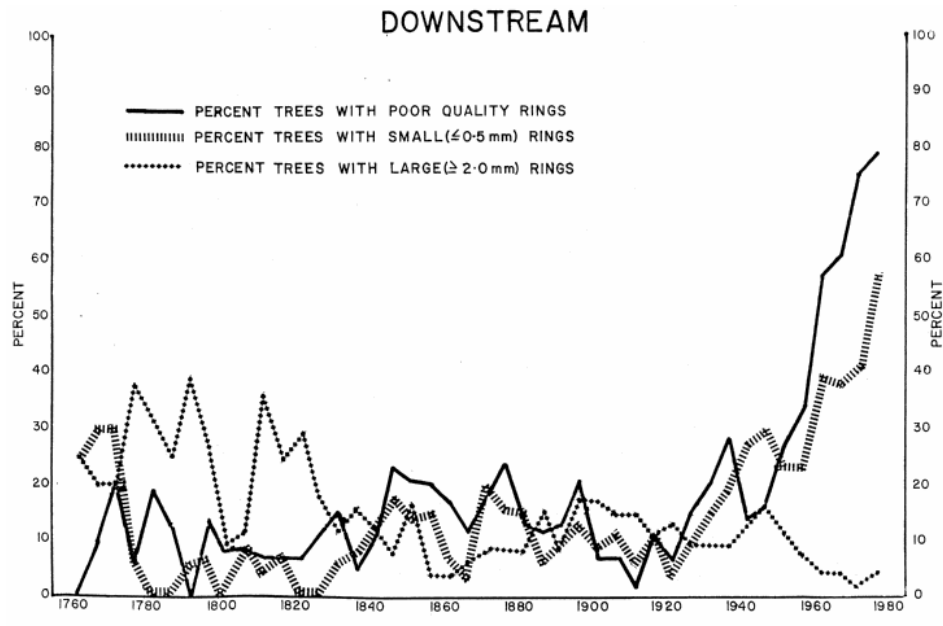
During April 1967, Taylor Alexander studied vegetation quadrats along a transect on the Northwest Fork of the Loxahatchee River near RM 7.5 (personal communication). His transect contained temperate and subtropical species, salt tolerant and non-salt tolerant species, and three classes of cypress trees: dead, stressed but living, and healthy. His transect was reexamined in the FDEP/SFWMD 2003 vegetative study and one living cypress was found.

Alexander and Crook (1975) utilized aerial photographs and groundtruthing to examine plant communities along the Northwest Fork of the Loxahatchee River and Kitching Creek (**Figure 3-1**). Upon identifying the signature of the most abundant community types, they were able to use photo interpretation to identify the major vegetative communities from a 1940 aerial photograph. Areas of dead and living cypress canopy within a mangrove understory were then field verified in 1970. They concluded that since 1940, areas of wet prairie and swamp hardwoods had been converted to pinelands and mangrove communities because of the lowered groundwater table and the saltwater encroachment between RM 6.0 and RM 8.0. They were able to identify areas of past logging in the aerial photographs, which could explain the loss of mature trees within portions of the watershed. Also, they mentioned the impact of fire, hurricanes and heavy frost on the major plant communities. At RM 6.5, they collected freshwater peat at a depth of 24 inches below the surface. Based on this information, they further concluded that there was no evidence that cypress forest had extended much further downstream than about RM 6. Finally, Alexander and Crook (1975) predicted that the mangrove invasion would accelerate, if anthropogenic activities in the upper floodplain of the river further reduced the freshwater head.

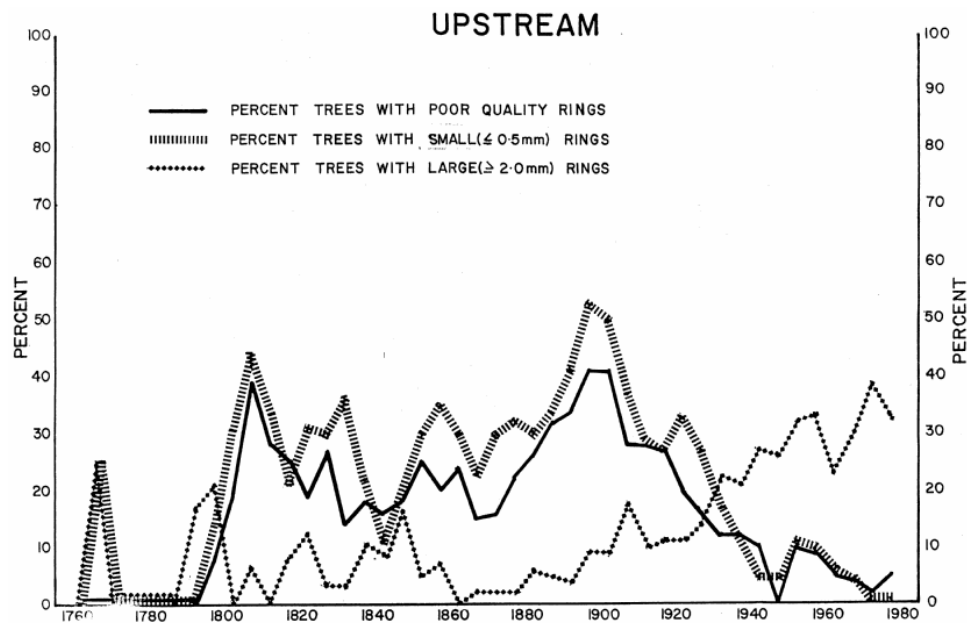


**Figure 3-1.** Photograph of the Northwest Fork of the Loxahatchee River taken in 1971 by T. Alexander.

Between 1979 and 1982, Duever (personal communication) documented the extent of environmental stress in the bald cypress community along the Northwest Fork of the Loxahatchee River. The study examined core samples collected from cypress trees at 21 sites (69 trees in total) located up and down the river to identify changes in tree rings over time. The results of the study indicated that although all of the trees sampled had experienced stress at periodic intervals during their life histories, the proportion of stressed trees downstream of RM 9.0 increased from 30 percent in 1940 to 80 percent in 1982 (**Figure 3-2**). The proportion of stressed trees upstream from RM 9.0 decreased from 11 percent to 3 percent during the same 40-year period (**Figure 3-3**). The study also found a high correlation between the incidence of growth stress and high salinity in surface water and soils.



**Figure 3-2.** Changes in Cypress Tree Ring Size and Quality Through Time Downstream of RM 9.0, Northwest Fork of the Loxahatchee River (from Duever, unpublished USGS data).



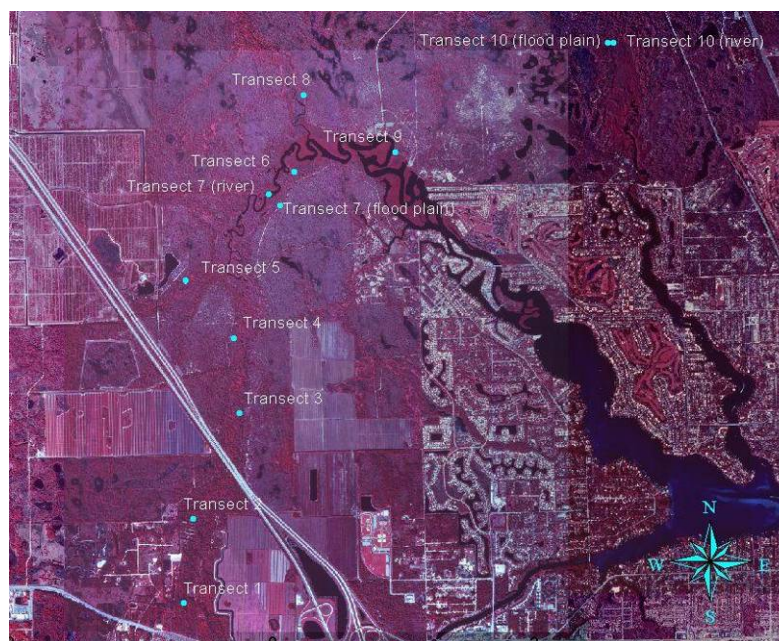
**Figure 3-3.** Changes in Cypress Tree Ring Size and Quality Through Time Upstream of RM 9.0, Northwest Fork of the Loxahatchee River (from Duever, unpublished USGS data)



McPherson (1981) studied the transitional area between the cypress forest community and the mangrove community on the Northwest Fork. In May of 1981, the surface salinities around an area of dead and stressed cypress were 20 to 30 ppt. In another area of intermediately stressed cypress, surface salinities ranged from 15 to 20 ppt. In areas with shallow groundwater, salinities decreased with depth below the land surface increased and distance from the river increased, especially in areas where fresh water seepage was observed from nearby higher pinelands. McPherson concluded that there was no evidence that cypress forest ever extended much further downstream from his Site 7E (approximately RM 5.5) on the Northwest Fork.

Dewey Worth established six, 10m wide vegetation transects along the Northwest Fork of the Loxahatchee River as a part of South Florida Water Management District's Loxahatchee River Restoration Plan (1983-1984). The transects were surveyed and ground and surface water elevations were recorded. In addition, several shallow water groundwater monitoring wells were established. SFWMD scientists have obtained the datasets to examine for trends.

Between October 1993 and January 1994, Ward and Roberts (1996) re-examined Worth's six vegetative transects between Indiantown Road (S.R. 706) and the mouth of Kitching Creek. Each 10m wide belt transect was partitioned into 10m<sup>2</sup> plots. A total of 79 plots were surveyed during the study. Generally the density (stems/hectare) of bald cypress (*Taxodium distichum*) increased upstream from Transect #6 (RM 8.4) near Kitching Creek to Transect #1 (RM 14.5) just north of S.R. 706. A noticeable decrease in cypress density occurred at Transect #3 (RM 12.1), which was heavily populated with pop ash (*Fraxinus caroliniana*), red maple (*Acer rubrum*) and cabbage palms (*Sabal palmetto*). These six transects (**Figure 3-4**) were re-examined in the 2003 vegetative study and four new transects were added. Comparisons of the 1993-1994 and 2003 vegetation studies are being prepared for a report summarizing the 2003 vegetation survey.

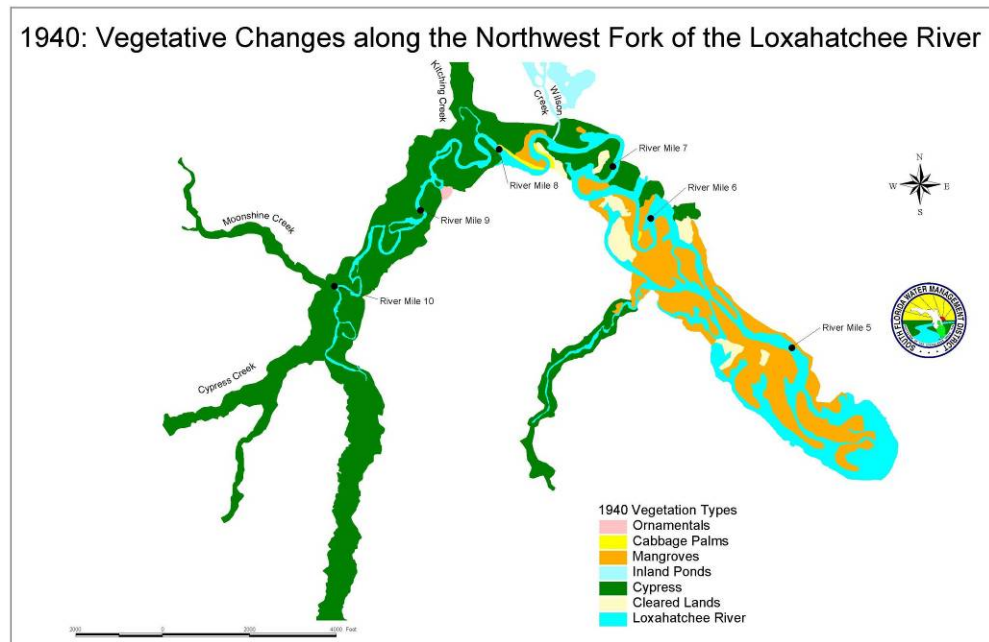


**Figure 3-4.** Location of the 10 Vegetation Transects of the Northwest Fork of the Loxahatchee River. Transects 1 – 6 are D. Worth transects (1983-1984); Transects 7 - 10 are additional Ward and Robert (1996) transects.

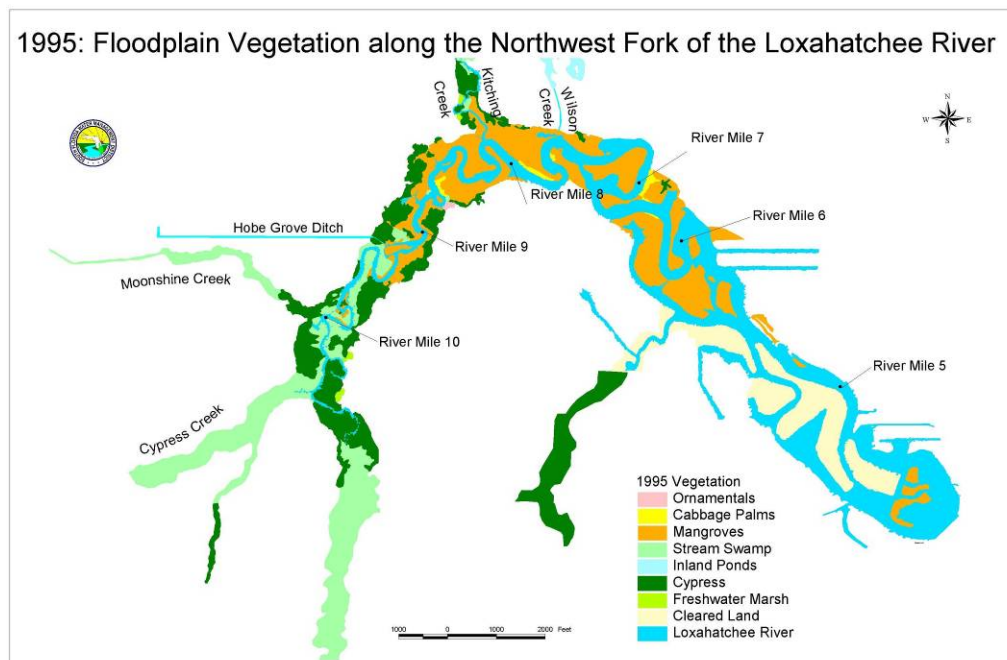
In an examination of aerial photography from 1940 to 1995, major vegetative communities were identified along the floodplains of the Northwest Fork of the Loxahatchee River (SFWMD, 2002). The results of the study indicated that the floodplain vegetation coverage had decreased due to bulkheading of the shoreline, filling for development, Jupiter Inlet stabilization in 1947, and changes in vegetation types (i.e. changes from wetlands to transitional and upland species, from marsh to mangrove, and from wet prairie to pine forest). The 1940 aerial photographs of the watershed indicate an abundance of swamps, wet prairies, inland ponds, and sloughs. Freshwater swamp hardwood and cypress communities were dominant from RM 4.5 to RM 8.9, comprising about 73% of the vegetative coverage, while mangroves represented 22% (**Figure 3-5**). Mangroves were dominant from RM 4.5 to RM 6.0 and were present upstream to RM 7.8. By 1985, freshwater communities represented 61% of the coverage, while mangroves represented 25% of the coverage. Mangroves were dominant between RM 5.5 and RM 8.7 and extended up to RM 10.5. It was noted that there was a loss of approximately 80 acres of mangroves due to development between RM 4.5 and RM 5.5. There were no major changes between cypress and mangrove floodplain coverages between 1985 and 1995 (**Figure 3-6**).

Semi-quantitative and quantitative vegetation surveys (species composition and abundance) were conducted along the Northwest Fork of the Loxahatchee River as a part of the Minimum Flows and Levels Project (Zahina, 2004). Twenty-three semi-quantitative sites were sampled in November 2000 and December 2001. Eight sites were re-investigated from the series of semi-quantitative survey sites to produce a quantitative database in 2002. The vegetation studies indicate a decline in species richness, reduction in tree height, reduction in canopy diameter, and in stem diameter that was related to salinity. The report addressed distribution of plant species and communicates along the salinity gradient, and the relationship between salinity exposure and freshwater floodplain decline.

In 2003 vegetation and groundwater monitoring studies were established for plant community composition and structure and groundwater in order to document baseline and future plant community health along the floodplains of the North and Northwest Forks of the Loxahatchee River and Cypress and Kitching Creeks. The project examined the six historical vegetation transects and establishing four new transects in additional areas of concern (**Figure 3-4**). These locations are representative of riverine (predominantly non-impacted freshwater) and upper tidal (saltwater intruded with fresh and brackish water) communities. Seven transects are located at designated locations along the middle and upper segments of the Northwest Fork of the Loxahatchee River. Additional transects were established in the lower segment of Kitching and Cypress Creeks (tributaries of the Northwest Fork), and in the upper North Fork of the Loxahatchee River. Data from the historical transects of Alexander (1967, unpublished), Worth (1984, unpublished SFWMD), and Ward and Roberts (1993-1994, unpublished) will be compared with the 2003 baseline data to determine changes in the composition and structure of these forest communities over time.



**Figure 3-5.** 1940 Aerial Interpretation of Floodplain Vegetative Communities Along the Northwest Fork of the Loxahatchee River.



**Figure 3-6.** 1995 Aerial Interpretation of Floodplain Vegetative Communities Along the Northwest Fork of the Loxahatchee River.

For the analysis of canopy data from the 2003 Vegetation study, plant communities of the floodplains of the Northwest Fork of the Loxahatchee River were divided into three distinct groups or reaches (**Table 3-1** and **Figures 3-7a and 3-7b**) **riverine (R)**, **upper tidal (UT)** and **lower tidal (LT)**. These groups were distinguished based on hydrological conditions, vegetation, and soils (modified from USGS, 2002a). The boundaries were based on distribution of the different canopy tree species using the 1995 aerial photography and the corresponding GIS coverage. The Northwest Fork of the Loxahatchee River contains approximately 320 hectares of riverine, 24 hectares of upper tidal and 45 hectares of lower tidal floodplain.

**Table 3-1.** Forest Community Types by Reach for the Northwest Fork of the Loxahatchee River and its Major Tributaries.

Forest Type	Riverine (R)	Upper Tidal (UT)	Lower Tidal (LT)
Swamp	Rsw1 Rsw2 (FPsw1 <sup>a</sup> )	UTsw1 UTsw2 (FPsw1 <sup>a</sup> ) UTsw3 (LRsw3 <sup>b</sup> )	LTsw1 (RMsw1 <sup>c</sup> ) LTsw2
Low Bottomland Hardwood	Rblh1 Rmix	UTmix	LTmix
High Bottomland Hardwood	Rblh2 Rblh3		
Hammock	H (Mesic and Hydric)	H (Hydric only)	H (Hydric only)
Upland	U	U	U

<sup>a</sup> Another name for *Fraxinus caroliniana* swamp.

<sup>b</sup> Another name for *Laguncularia racemosa* swamp.

<sup>c</sup> Another name for *Rhizophora mangle* swamp.

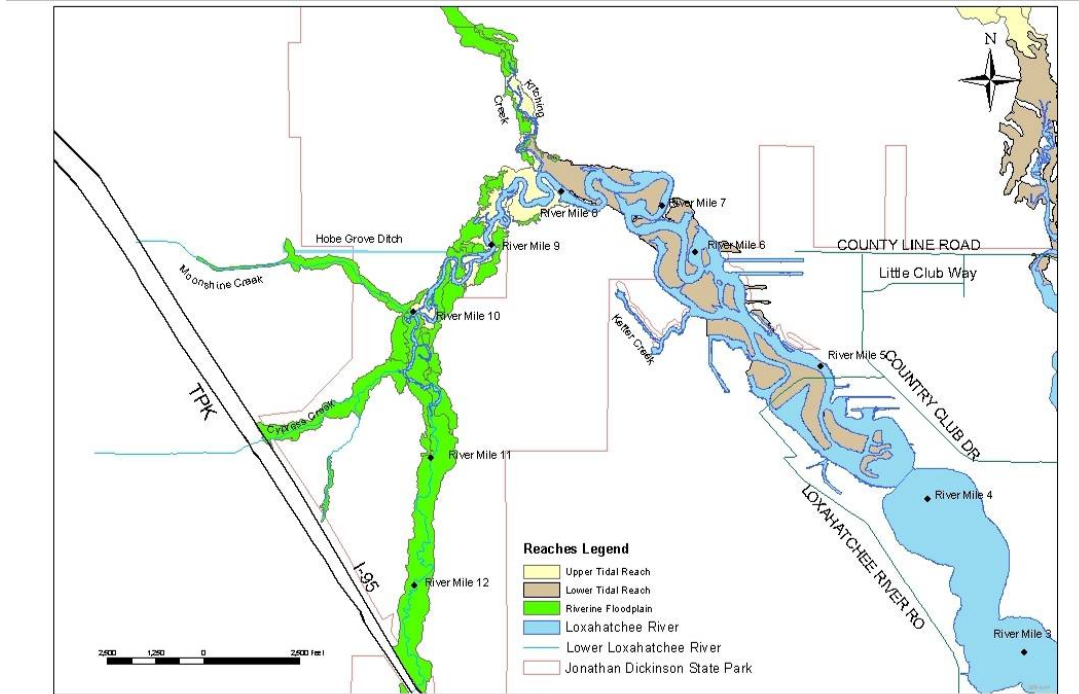
Riverine reach information is generally presented in this report with a green background color. Upper tidal reach information is generally presented in this report with a yellow background color. The lower tidal reach information in this report is generally presented with a beige color background.

The riverine reach is that part of the floodplain forest having primarily freshwater canopy forest that is generally unaffected by salinity. On the Northwest Fork of the Loxahatchee River, this area ranges from just north of the G-92 Structure (**Figure 3-7b**) downstream to RM 9.5 (**Figure 3-7a**). Vegetative communities in this reach are dominated by bald cypress (*Taxodium distichum*) with pop ash (*Fraxinus caroliniana*), red maple (*Acer rubrum*), pond apple (*Annona glabra*), water hickory (*Carya aquatica*) and other trees present with less frequency.

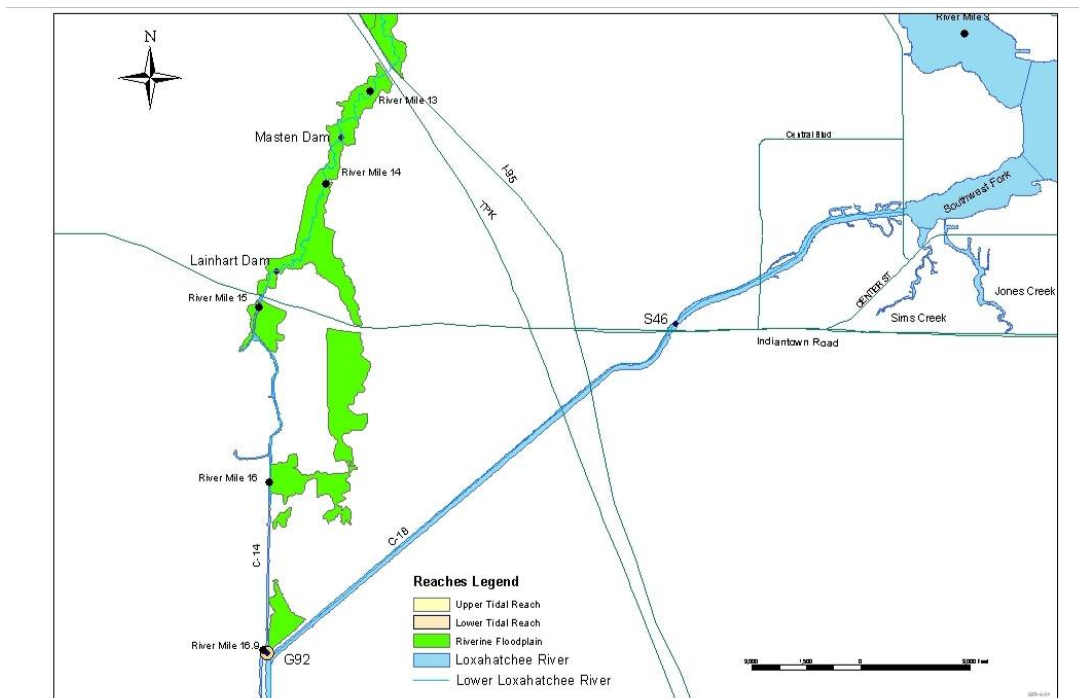
The upper tidal reach is that part of the floodplain forest having a mixed freshwater/brackish canopy forest that has experienced some salt water intrusion due to tidal influences and lack of freshwater flow in the dry season. On the Northwest Fork of the Loxahatchee River this area occurs between RM 9.5 and RM 8.13 (the mouth of Kitching Creek), as illustrated in **Figure 3-7a**. Upper tidal reach communities are dominated by pond apple, red and white mangrove (*Rhizophora mangle* and *Laguncularia racemosa*) and cabbage palm (*Sabal palmetto*) with some communities of bald cypress present in the inner floodplain areas away from the riverbed.

The lower tidal reach is that part of the Northwest Fork having primarily salt tolerant species and is highly influenced by tides and salinity in the water and soils (**Figure 3-7a**). This area extends from approximately RM 8.13 to RM 5.5 although several smaller areas can be found around RM 4.5 and in the embayment area. The lower tidal reach is dominated by red and white mangrove.





**Figure 3-7a.** Reaches of the Northwest Fork of the Loxahatchee River Between RM 4.5 and RM 12.76.



**Figure 3-7b.** Upper Riverine Reach of the Northwest Fork of the Loxahatchee Between I-95 (RM 12.76) and the G-92 Structure.

## DESCRIPTION OF FLOODPLAIN FOREST COMMUNITIES

The identification of floodplain forest community type was based on the canopy tree species that generally grow together in recognizable communities (modified from Darst et al., 2003). Tree canopy data from both the 1995 Ward and Roberts study (76 10m<sup>2</sup> plots) and the 2003 transect study (130 10m<sup>2</sup> plots) were collected; the relative basal area (RBA) of each tree species within a plot was determined using diameter at breast height (dbh) measurements. RBA is calculated by dividing the total basal area of a species (in m<sup>2</sup>) by the total basal area of all species within a 10m<sup>2</sup> plot. Multi-trunk trees were considered separate trees for this analysis. The most common multi-trunk trees observed were pond apple (*Annona glabra*), red mangrove (*Rhizophora mangle*) and bald cypress (*Taxodium distichum*).

### Forest Community Types

Guidelines were developed to identify the 15 forest community types by reach (**Table 3-2**). For each area, the major vegetative community category was identified as swamp (S), bottomland hardwood (low and high Blh), hydric or mesic hammock (H), or uplands (U). Then the reach and type of the forest community was determined based on species composition. Using these guidelines, it was possible to consistently distinguish among forest community types (i.e., distinguish a riverine swamp community from an upper tidal swamp community).

Split plots and mixed plots also occurred. A split plot had two major forest types split 50%-50% relative basal area (RBA) on either side of the plot such as Hammock/Rsw1. A mixed plot has several forest types intermixed together within the plot. These plots were classified as Rmix, UTmix, or LTMix. A total of 28 canopy species were identified during the 2003 belt transect survey and were categorized by their most common occurrence in the floodplains. Forest types clearly differ as a result of changes in hydrology, topography, vegetation, soils, and proximity to the coast (Darst et al., 2003). Other factors that influence forest type include logging and fire history, presence or absence of exotic species, and the availability of nutrients and light.

DuBois wrote in her book “The History of the Loxahatchee River” (1981) that logging leases to two townships on the Loxahatchee were purchased by the Hunt brothers from Green Cove Springs in 1891. Other logging operations were conducted, cutting pine from the uplands and cypress from the river’s edge. After logging a portion of their property, local pioneers, John and Bessie DuBois purposely saved 27 large cypress trees on Kitching Creek. The last recorded logging operations on the Loxahatchee River were in 1941. The cypress swamp community on the Upper Northwest Fork near Indiantown Road (S.R. 706) remains largely intact. Many of the cypress trees along this reach of the river range from 300 to 500 years in age. Evidence of past logging activities on the Transects #3, #6, and #7 was verified by the presence of tree stumps without the fallen trees.

Oak/pine upland forests are present in both the riverine and tidal reaches of the floodplain and are inundated only for short periods of time during the highest floods. Most of the species found in this forest community type can only survive brief periods of inundation. On the Northwest Fork of the Loxahatchee River, these upland systems are dominated by slash pine (*Pinus elliottii*), myrtle oak (*Quercus myrtifolia*) and saw palmetto (*Serenoa repens*). Brazilian pepper (*Schinus terebinthifolius*) may occur as an exotic pest species in many of the forest community types if there is sufficient elevation for its growth.

**Table 3-2.** Guidelines for Determining Reach and Forest Type (2003 Canopy Study) in the Floodplains of the Loxahatchee River and its Major Tributaries (modified from Light et al., 2003).

Category		Species	Rules for Determination of Reach
Swamp	Riverine	<i>Fraxinus caroliniana</i> <i>Taxodium distichum</i>	1) IF <i>Taxodium distichum</i> + <i>Fraxinus caroliniana</i> + <i>Acer rubrum</i> + <i>Carya aquatica</i> > 80% THEN reach is riverine. 2) IF <i>Taxodium distichum</i> + <i>Acer rubrum</i> + <i>Carya aquatica</i> < 20% and <i>Annona glabra</i> + <i>Fraxinus caroliniana</i> > 60% OR 3) IF <i>Rhizophora mangle</i> + <i>Laguncularia racemosa</i> + <i>Fraxinus caroliniana</i> > 60%, THEN reach is upper tidal. 4) IF <i>Rhizophora mangle</i> > 80% OR 5) IF <i>Rhizophora mangle</i> + <i>Laguncularia racemosa</i> > 75% and <i>Annona glabra</i> < 10%, THEN reach is lower tidal.
	Tidal	<i>Annona glabra</i> <i>Laguncularia racemosa</i> <i>Rhizophora mangle</i>	
Bottomland Hardwood (blh)	Low	<i>Acer rubrum</i> <i>Cephalanthus occidentalis</i> <i>Persea palustris</i> <i>Salix caroliniana</i> <i>Syzygium cumini</i>	<b>Rules for Determination of Forest Type</b> 1) IF Upland ≥ 75%, THEN forest type is upland. 2) IF Upland < 50% and hammock > 50%, THEN forest type is hammock. <b>Riverine reach forest types:</b> 1) IF riverine swamp > 50% THEN 2) IF <i>Taxodium distichum</i> ≥ 80%, OR 3) IF <i>Taxodium distichum</i> + <i>Fraxinus caroliniana</i> ≥ 80% and <i>Taxodium distichum</i> > 50% THEN forest type is Rsw1. 4) IF <i>Fraxinus caroliniana</i> ≥ 80%, OR 5) IF <i>Taxodium distichum</i> + <i>Fraxinus caroliniana</i> > 80% and <i>Fraxinus caroliniana</i> > 50%, THEN forest type is Rsw2. 6) IF <i>Taxodium distichum</i> < 50% and hammock > 40% but < 60 % THEN forest type is Rmix. 7) IF riverine swamp < 50% THEN 8) IF low blh > 80%, OR 9) IF <i>Acer rubrum</i> ≥ 80%, THEN forest type is Rblh1. 10) IF high blh + low blh > 80% and high blh > 50%, THEN forest type is Rblh2. 11) IF high blh + up or hammock ≥ 70%, THEN forest type is Rblh3. 12) IF hammock ≥ 80%, OR 13) IF hammock + high blh is > 80% and hammock > 50%, Then forest type is hammock.
	High	<i>Carya aquatica</i> <i>Chrysobalanus icaco</i> <i>Citrus spp.</i> <i>Ilex cassine</i> <i>Psidium cattleianum</i> <i>Quercus laurifolia</i> <i>Roystonea regia</i>	
Hammock		<i>Ficus microcarpa</i> <sup>a</sup> <i>Ficus aurea</i> <sup>a</sup> <i>Myrica cerifera</i> <i>Persea borbonia</i> <i>Quercus virginiana</i> <sup>c</sup> <i>Sabal palmetto</i> <sup>d</sup>	<b>Upper tidal reach forest types:</b> 1) IF mixed swamp <sup>b</sup> ≥ 70% and <i>Laguncularia racemosa</i> < 30%, THEN forest type is UTsw1. 2) IF mixed swamp < 70% and <i>Annona glabra</i> > 30%, THEN forest type is UTsw2. 3) IF <i>Laguncularia racemosa</i> > 50% THEN forest type is UTsw3. 4) IF mixed swamp < 50% and hammock + upland > 60% OR 5) IF hammock + blh < 75%, THEN forest type is Utmix. 6) IF hammock > 75%, THEN forest type is hammock.
			<b>Lower tidal reach forest types:</b> 1) IF LT swamp > 50% OR 2) IF <i>Rhizophora mangle</i> is > 80%, THEN forest type LTsw1. 3) IF <i>Laguncularia racemosa</i> + <i>Annona glabra</i> is > 70%, THEN forest type is LTsw2. 4) IF LT swamp < 50% THEN, 5) IF <i>Sabal palmetto</i> ≥ 50% and <i>Laguncularia racemosa</i> + <i>Annona glabra</i> > 40%, THEN forest type is LTmix 6) IF <i>Sabal palmetto</i> + <i>Chrysobalanus icaco</i> ≥ 75%, THEN forest type is hammock.
Upland		<i>Pinus elliotii</i> <i>Quercus myrtifolia</i> <i>Schinus terebinthifolius</i> <i>Serenoa repens</i>	

<sup>a</sup> Present as epiphytes at Transects 7 and 9.

<sup>b</sup> Both riverine and tidal swamp species present.

<sup>c</sup> Dominant canopy species in Mesic Hammock.

<sup>d</sup> Dominant canopy species in Hydric Hammock.

Species in Red Font-are Exotics.



Hammocks are also found in both the riverine and tidal reaches of the Loxahatchee River. Hammocks support a vast diversity of tropical and subtropical plants including hardwood trees, palms, orchids and other epiphytes (Mitch and Gosselink, 1993). Hydric hammock communities are dominated by cabbage palms (*Sabal palmetto*) whereas mesic hammocks are dominated by live oaks (*Quercus virginiana*). Mesic hammocks are found at higher elevations than hydric hammocks. No mesic hammocks were found in the tidal reaches of the Loxahatchee River. Other fairly common species in hammock areas are myrsine (*Rapanea punctata*), mulberry (*Morus rubra*), red bay (*Persea borbonia*), and ficus (*Ficus aurea*). Hammocks are generally found between the uplands, bottomland hardwood and swamp areas, although with changes in elevation within the floodplain they may appear as isolated islands or may border the riverbed where elevations are higher. Hammocks are briefly inundated by storm surges but characteristically have a high water table due to their proximity to deeper wetland areas. Hydric hammocks are flooded continuously for several weeks or longer every 1 to 3 years depending on reach. Mesic hammocks are rarely flooded because of their high elevations. Soils are generally sandy in both types of hammock.

In the riverine reach, high bottomland hardwoods are found on higher ridges while low bottomland hardwoods are found on swamp margins. Periods of inundation generally occur for 1 to 2 months every few years for high bottom land hardwood (Rblh2 and Rblh3) and about 2 months of every year for low bottomland hardwood (Rblh1). Characteristic Rblh1 species red maple (*Acer rubrum*), buttonbush (*Cephalanthus occidentalis*), swamp bay (*Persea palustris*) and Carolina willow (*Salix caroliniana*) while characteristic Rblh3 species are water hickory (*Carya aquatica*), cocoplum (*Chrysobalanus icaco*), dahoon holly (*Ilex cassine*), and laurel oak (*Quercus laurifolia*). The forest type Rblh1 is characterized by a dominance of red maple and is found at lower elevations than either Rblh2 or Rblh3. The forest type Rblh2 has approximately equal amounts of low and high bottomland species whereas the Rblh3 forest has combinations of high bottomland mixed with hammock species or even some upland representatives. The Riverine Mixed (Rmix; **Figure 3-8**) forest type is characterized by even more disparate species: bald cypress and hammock species are almost equally mixed. The exotic plant species, java plum (*Syzygium cumini*) and strawberry guava (*Psidium cattleianum*) are found in disturbed areas of the riverine and tidal bottomland hardwoods. The occurrence of a few royal palms (*Roystonea regia*) is attributed to their spread from the adjacent Ornamental Garden property. Java plum and strawberry guava may have been introduced by Trapper Nelson.

Riverine swamps are characterized with the lowest elevations and wettest areas with either inundation or saturation most of the year. Soils are generally sandy with some loam and clay. On the Northwest Fork of the Loxahatchee River, older riverine swamps are dominated primarily by bald cypress (*Taxodium distichum*) communities (Rsw1; **Figure 3-9**), while younger subcanopy swamp communities and impacted areas (i.e. logged) are dominated by pop ash (*Fraxinus caroliniana*, Rsw2). Occasional bald cypress/cabbage palm (swamp/hammock) and bald cypress/red maple/cabbage palm (swamp/low bottomland hardwood/hammock) communities are present and are categorized as Riverine Mixed (Rmix). Pond apples are found in the riverine swamps but are generally only associated with the riverbanks.



**Figure 3-8.** Example of Forest Type Rmix (Pond Apple, Bald Cypress, Red Maple, Wax Myrtle, Cabbage Palm in a Selectively Logged Area).



**Figure 3-9.** Example Forest Type Rsw1 (Bald Cypress Swamp).



Lower tidal forest types are primarily mangrove forest (i.e. swamps) with some areas of hammock which represent areas with very little change in topography within the floodplains. Soils are generally mucky with some areas of sand. LTsw1 is representative of a swamp dominated by red mangrove (**Figure 3-10**). The LTsw2 is representative of a white mangrove swamp with infrequent pond apple and red mangrove (**Figure 3-11**). Other plots contain mixtures of white mangrove, pond apple, and cabbage palm. If cabbage palm is at least 50% and white mangrove and pond apple are greater than 30% then the forest type is identified as lower tidal mixed (LTmixed). If cabbage palm and cocoplum (*Chrysobalanus icaco*) are greater than 75% then the forest type is identified as hammock. Cabbage palm is found intermixed and in clumps with swamp species; however those palms that were found at these low elevations and exposed to salt water did not appear to be as healthy as those found at obviously higher elevations. Other palms were found growing on small mounds of hummocks. Today, cabbage palms are quite common along the shoreline of the tidal Northwest Fork of the Loxahatchee River. The river channel has widened between 1940 and 1995 along the shoreline between the JDSP boundary and Trapper Nelson's Interpretative Site (SFWMD, 2002). This widening suggests that erosion has occurred within these cabbage palm communities leaving them exposed to greater tidal fluctuations and saltwater exposure.

Mangrove-swamp is the dominant feature of the lower tidal reach and the embayment area. The dominant species are red mangrove, *Rhizophora mangle*, and white mangrove, *Laguncularia racemosa*. Black mangroves, *Avicennia germinans*, are occasionally found among white mangrove; however, they are more frequent along the Atlantic Intracoastal Waterway system. Presently, mangroves first appear as thin borders of vegetation along natural shorelines of the estuary and begin to occur as substantial "forest" at approximately RM 6.0 of the Northwest Fork of the Loxahatchee River. They are eventually replaced by a floodplain swamp community by RM 10.0.



**Figure 3-10.** Example Forest Type LTsw1 (Red Mangrove Swamp).





**Figure 3-11.** Example Forest Type LTsw2 (White Mangrove Swamp with Dead Bald Cypress).

Mangroves are very salt tolerant and tend to colonize shorelines where the substrate has been stabilized or protected from the effects of wave action or erosion. The continued spread of mangroves upstream in the river floodplain, displacing less salt tolerant species such as cypress and hardwoods, has been viewed as an impact to the ecosystem. These slow changes in river vegetation communities over time are linked to the combined effects of saltwater intrusion caused by permanent stabilization of Jupiter Inlet, dredging of the estuary, construction of C-18 canal and reduced flows from the headwaters.

Even though the spread of mangroves into formerly freshwater environments is viewed as an adverse condition for the river, mangroves serve an important role in the estuary ecosystem, since these plants provide a stable substrate for many other species to colonize (Savage, 1972). Mangroves are also a significant source of primary productivity and the physical and bacterial decomposition of mangrove leaf litter provides a major food source for detritivores in the estuary food chain (Heald and Odum, 1970). Mangroves are susceptible to frost damage and may be highly impacted during a hard freeze.

### **Threatened or Endangered Plants**

In addition to the dominant species used to define forest communities along the Northwest Fork of the Loxahatchee River State, many rare, endangered, or threatened plants also coexist in these communities. Within Jonathan Dickinson State Park alone, there are 29 species plants that are protected by the state or federal government. A list of protected plant species that occur within the Northwest Fork watershed are shown in **Table 3-3**.

**Table 3-3.** Threatened and Endangered Wetland Plant Species in the Loxahatchee River Watershed.

Scientific Name	Common Name	FCREPA <sup>a</sup>	FDA <sup>b</sup>	USFWS <sup>c</sup>
<i>Actinostachys pennula</i>	Fern ray/Tropical curly-grass fern		E	
<i>Asclepias curtissii</i>	Curtiss' milkweed		E	
<i>Asimina tetramera</i>	Four-petal pawpaw		E	E
<i>Azolla caroliniana</i>	Mosquito fern		T	
<i>Bletia purpurea</i>	Pine pink orchid		T	
<i>Calopogon barbatus</i>	Bearded grass pink		T	
<i>Calopogon multiflorus</i>	Many-flowered grass pink		E	
<i>Campyloneurum latum</i>	Strap fern		E	
<i>Campyloneurum phyllitidis</i>	Long strap fern		E	
<i>Chamaesyce cumulicola</i>	Sand dune spurge		E	
<i>Chrysophyllum oliviforme</i>	Satinleaf		E	
<i>Cladonia perforata</i>	Perforate reindeer lichen		E	E
<i>Conradina grandiflora</i>	Large-flowered rosemary		E	
<i>Drosera intermedia</i>	Water sundew		T	
<i>Encyclia cochleata</i>	Clamshell orchid		E	
<i>Epidendrum rigidum</i>	Rigid epidendrum		E	
<i>Ernodea littoralis</i>	Beach creeper		T	
<i>Eulophia alta</i>	Wild coco		T	
<i>Habenaria nivea</i>	Snowy orchid		T	
<i>Halophila johnsonii</i>	Johnson's seagrass			T
<i>Lechea cernua</i>	Nodding pinweed		T	
<i>Lechea divaricata</i>	Pine pinweed		E	
<i>Lilium catesbaei</i>	Catesby's lily		T	
<i>Nemastylis floridana</i>	Celestial lilt	T	E	
<i>Nephrolepis biserrata</i>	Giant sword fern		T	
<i>Ophioglossum palmatum</i>	Hand adder's tongue fern	E	E	
<i>Peperomia humilis</i>	Low peperomia		E	
<i>Phlebodium aureum</i>	Polyploidy fern		T	
<i>Pinguicula caerulea</i>	Blue-flowered butterwort		T	
<i>Pogonia ophioglossoides</i>	Rose pogonia		T	
<i>Polygala smallii</i>	Small's milkwort		E	E
<i>Psilotum nudum</i>	Whisk fern		T	
<i>Pteroglossaspis ecristata</i>	Non-crested coco		T	
<i>Sacoila lanceolata</i>	Leafless red beak orchid		T	
<i>Salvinia minima</i>	Water spangles		T	
<i>Spiranthes laciniata</i>	Lace-lip ladies' tresses		T	
<i>Spiranthes vernalis</i>	Ladies' tresses		T	
<i>Thelypteris interrupta</i>	Aspidium fern		T	
<i>Thelypteris kunthii</i>	Aspidium fern		T	
<i>Thelypteris palustris</i>	Aspidium fern		T	
<i>Thelypteris serrata</i>	Dentate lattice vein fern		E	
<i>Tillandsia balbisiana</i>	Inflated wild pine		T	
<i>Tillandsia fasciculata</i>	Common wild pine		E	
<i>Tillandsia flexuosa</i>	Twisted air plant	T	E	
<i>Tillandsia utriculata</i>	Giant wild pine		E	
<i>Tillandsia variabilis</i>	Soft-leaved wild pine		T	
<i>Tolumnia bahamensis</i>	Dancing lady orchid		E	

Data from Treasure Coast Regional Planning Council, 1999. Jonathan Dickinson State Park Unit Management Plan -State of Florida Department of Environmental Protection, February 2000.

<sup>a</sup> Florida Committee on Rare and Endangered Plants and Animals

<sup>b</sup> Florida Department of Agriculture and Consumer Services

<sup>c</sup> United States Fish and Wildlife Service. E=Endangered, T=Threatened.

## TRANSECT VEGETATION SUMMARIES

In the 2003 vegetation survey of the Northwest Fork of the Loxahatchee River, Transects #1, #2, #3, and #4 were examples of riverine forest types. Transects #6 and #7 were examples of the upper tidal reach and Transect #9 was an example of the lower tidal reach. The forest type of each 10m<sup>2</sup> plot based on relative basal area is shown in **Appendix A**, while total number of canopy trunks by species by transect is shown in **Appendix B**. Survey profiles of each transect are illustrated in **Appendix C** and express elevation as feet NGVD29.

### Riverine Transects

Transect #1 is located just downstream of Lainhart Dam at RM 14.5. This transect transverses the north and south sides of the Northwest Fork with 15 10m<sup>2</sup> plots (**Table 1A, Appendix A**). It has several elevation changes from 13.74 feet NGVD at the top of the mesic hammock to about 9.34 feet NGVD in the deeper swamp areas and 5.44 feet NGVD in the river channel (**Appendix C**). The exterior sides of Transect #1 are dominated by several plots of upland and hammock before dropping down into the floodplains as a cypress swamp (Rsw1) that borders the riverbed. One higher area adjacent to the bank of the river is classified as Rblh1 because red maple occurs within the plot and water hickory just outside of the measured plot. Cabbage palm, live oak (*Quercus virginiana*), and slash pine dominate the hammock and uplands plots while a stand of mostly very old bald cypress with an average dbh of 49 cm dominates the Rsw1 plots (**Appendix B**). The smallest bald cypress has a dbh of 9.9 cm. Because the canopy is well established and there are high flow velocities in this area, there is very little indication of a shrub layer at this transect. Also, there is no evidence of logging (i.e. stumps only) in this area. Shrubs and groundcover in the Rsw1 areas are dominated by swamp lily (*Crinum americanum*), tri-veined fern (*Thelypteris interrupta*) and downy shield fern (*Thelypteris dentata*). The exotic plants elephant ear (*Xanthosoma sagittifolium*) and arrowhead vine (*Syngonium podophyllum*) were also present as groundcover within the cypress swamp community.

Transect #2-1 is located at RM 13.6 just upstream of the western side of Masten Dam while Transect #2-2 is located downstream of Masten Dam (RM 13.4) on the same side of the river. There are several elevation changes between hammocks (approximately 9 feet to 11 feet NGVD), a very deep cut braided stream (6.32 feet NGVD), and the swamp areas (approximately 7.47 feet to 8.47 feet NGVD; **Appendix C**). Water appears to flow continuously through the cut, which is connected to the river above and below Masten Dam. Transect #2-2 has more hammocks (3.5 out of 6 plots) than does Transect #2-1 (3 out of 7 plots). Three and a half of the four plots on Transect #2-2 are mesic hammock (**Appendix A and B, Table 1B**). The Rsw1 and the Rmix plots are a little more diverse with younger pop ash, red maple and water hickory intermixed with the bald cypress. Bald cypress had an average dbh of 73.6 cm with the largest dbh at 114.5 cm while red maple and pop ash, average 23 cm and 9.7 cm, respectively. Also, there is one water hickory with a dbh of 9.2 cm. The smaller size of the red maple, pop ash and water hickory may indicate a trend towards subcanopy species that prefer shorter hydroperiods than bald cypress. The larger size of these bald cypress trees suggests that they may be several hundred years old, whereas the smaller red maple, pop ash, and water hickory may be no more than a few decades old (NPS, 1984). This marked age difference may indicate that other deciduous tree species are taking advantage of the shortened hydroperiods experienced by the older bald cypress community during the last 50 years. Shrubs and groundcover are primarily tri-veined fern, leather fern, swamp fern, Virginia willow, downy shield fern, royal fern, lizard's tail, and swamp lily. Witch grass (*Dichanthelium commutatum*) is prevalent in the Rblh1 plot.



Transect #3 is located at RM 12.1 downstream of I-95 and the Florida Turnpike on the east side of the river. The site has been heavily impacted by selective logging in the past and by the presence of Old World climbing fern (*Lygodium microphyllum*). There are multiple braided streams within the floodplains at this site. Elevations range from 5.54 feet NGVD at the benchmark to 2.03 feet NGVD at the bottom of the braided streams, and -9.87 feet NGVD in the river channel (**Appendix C**). The majority of the floodplain has an elevation of approximately 4 feet NGVD in this area. Nine of the 13 plots are either Rsw1 or Rsw2 (**Appendix A, Table 1C; Appendix B**). Bottomland hardwood and hammock are present near the uplands and adjacent to the riverbed. Transect #3 has the highest concentration of pop ash of any of the 10 transects. The average dbh is 17 cm for pop ash; however, the range is 5 cm to 41 cm. Only 4 bald cypress trees are present within the transect canopy and they are very large with an average dbh of 91.5 cm. Pond apple and red maple trees are also present with an average dbh of 7.1 cm and 14.4 cm, respectively. Shrubs and groundcover on Transect #3 are primarily leather fern, maiden fern, meniscium fern, and lizard's tail.

Transect #4 is located at RM 11.18 on the west side of the river approximately 1 mile upstream of Trapper Nelson's Interpretive Site. This transect is just downstream from an old logging road that crossed the floodplains and river. There are several elevation changes between the upland edge of the floodplain and the riverbed. The benchmark for this site is a very large dead pine tree, which is on the slope at about 5.62 feet NGVD. From the hammock the transect drops down into several Rsw1 plots intermixed with plots of Rlbh2 and Rlbh3 (**Appendix A, Table 1D; Appendix B**). Bottom elevations of the swamp plots are approximately 2.17 feet NGVD while the bottom of the river channel is -2.45 feet NGVD (**Appendix C**). Most of the plots closer to the river are bottomland hardwood with some of the largest water hickory observed in the watershed (**Figure 3-12**). Some of these large hickory trees exhibit the allelopathic nature of this species as little groundcover or shrubs are present beneath their canopy. Elevations of the Rlbh2 and Rlbh3 plots are approximately 2.51 feet to 3.91 feet NGVD. The average dbh of water hickory on the transect is 36.1 cm and with the largest at 88.6 cm. Bald cypress trees vary considerably in size and age across Transect #4. The average cypress dbh is 30.0 cm; but the dbh ranges from 5.7 cm to 83.6 cm indicating that several generations of trees are present. Pop ash and red maple averaged 12.2 cm and 11.0 cm dbh, respectively. Shrubs and groundcover are primarily leather fern, maiden's fern, downy shield fern, Virginia willow, swamp fern, royal fern, lizard's tail, swamp lily, and pond apple. Witch grass is present on the bottomland hardwood plots.



**Figure 3-12.** Water Hickory in Bottomland Hardwood Plot on Transect #4.

## Tidal Transects

Of the three tidal transects on the Northwest Fork of the Loxahatchee River, two sites are upper tidal (Transects #7 and #6) and one site is lower tidal (Transect #9). The elevations of these transects are generally lower, more gently sloping towards the river, and have fewer braided streams than those transects in the riverine reach. There were no bottomland hardwood plots in the tidal reaches although indicator species for these forest types are present. In the tidal reaches, canopy diversity is increased by the presence of hummocks (i.e. elevated mounds), cypress stumps, and fallen logs. Hummocks allow canopy species that would not normally be present in swamp communities to successfully occupy areas of lower elevation (**Figure 3-13**). Forest types in the tidal reaches are generally mixtures of swamp species (fresh and brackish water species), and mixtures of swamp, hammock, and upland. Based on historical records and aerial photography, the most abundant vegetative species in the tidal reaches of the Northwest Fork of the Loxahatchee River were bald cypress and cabbage palm. Based on a 1860s military drawing, the Northwest Fork of the Loxahatchee River only passage by canoe upstream of the mouth of Kitching Creek, whereas today the river is navigable by boat for an additional 2.2 miles upstream from Kitching Creek. Salt water intrusion, increasing sea level rise, lowered groundwater levels, and decreasing freshwater inflows have resulted in the increase in the distribution of red and white mangroves throughout the tidal reaches. In addition, historical logging, fire, freezes, exotic plants (Old World climbing fern, Brazilian pepper, java plum and strawberry guava), and erosion of the river channel have impacted sections of our tidal transects.



**Figure 3-13.** Cabbage Palm Utilizing a Hummock Among Red Mangroves and Pond Apples (UTsw1) on Transect #6.



Transect #6 is located at RM 8.4 on a peninsula just upstream of Kitching Creek and adjacent to National Audubon's Ornamental Garden (Kitching Creek Sanctuary). This peninsula has been selectively logged in the past and contains the remnants of many dead cypress trees. Today, there are still live cypress trees growing among the pond apples and mangroves and a band of cypress trees still exist adjacent to the uplands. Elevations range from 6.82 feet NGVD in the uplands to an average elevation of 1.59 feet NGVD over the remaining length of the transect (**Appendix C**). Of the 16 plots on Transect #6, there are 2 Upland, 1 Rsw1, 6 UTsw1, 6 UTsw3, and 1 UTmix plots (**Appendix A, Table 1E**). The most prevalent species are red and white mangrove and pond apple with an average dbh of 8.3 cm (**Appendix B**). Red maple (dbh 17.5 cm) and pop ash (average dbh 5.7 cm) are present in much smaller numbers. The average dbh of the living bald cypress trees is 29.8 cm. Approximately 85 meters from the uplands on Transect #6, there is a large, healthy bald cypress tree totally surrounded by red mangroves. Red mangrove and pond apple are more prevalent in the plots beyond 110 meters from the uplands, which demonstrates the significance of floodplain topography in species distribution. Shrubs and groundcover consist primarily of very young red and white mangrove, leather fern, pond apple, buttonbush, maiden fern, swamp fern, and rubber vine (*Rhabdadenia biflora*).

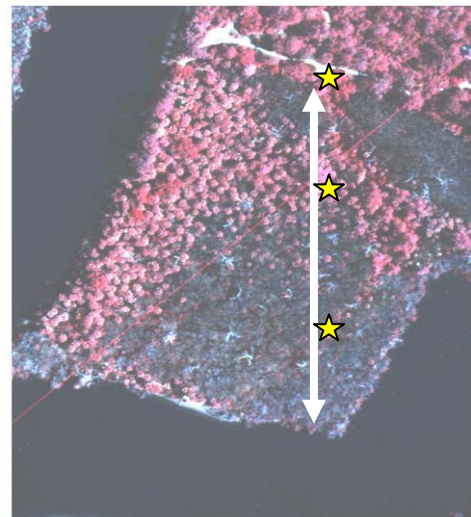
Transect #7 is located at RM 9.1 on the south side of the mid Northwest Fork across from the eastern end of Hobe Grove Ditch. This transect has been impacted by salt water intrusion, exotic vegetation (mostly Old World climbing fern, Brazilian pepper, and java plum) and logging. It is a very long transect with 15 plots that contain a mixture of 8 riverine and 7 upper tidal forest type plots (**Appendix A, Table 1F, and Appendix B**). Elevations change from 10.06 feet NGVD at the benchmark to an average of 1.58 feet NGVD across most of the floodplain (**Appendix C**). The riverine section of the transect consists of a mixed plot (Hammock/Rsw1) with live oak, wax myrtle, and a large cypress (50.1 cm dbh) followed by 2 plots of Rsw1, and 5 plots of Rmix (primarily bald cypress, cabbage palm and wax myrtle). Cabbage palm and wax myrtle coexist with the swamp species by living on small hummocks, old logged cypress stumps, and other fallen logs. The Upper Tidal segment of Transect #7 has 4 plots of UTsw1 and 3 plots of UTsw2. At a distance of 120 m from the upland, red mangroves begin to appear and become more abundant along with pond apples. White mangroves were present but too small to be considered canopy (i.e. dbh <5 cm). Live bald cypress trees are present from the edge of the uplands out to 120 m of the 150-meter transect. The bald cypress trees have an average dbh of 28.3 cm and range from 7.2 cm to 50.1 cm dbh. Shrubs and ground cover consist primarily of leather fern, wax myrtle, buttonbush, salt bush, primrose willow, poison ivy, swamp fern, marsh fern, meniscium fern, royal fern, swamp lily, milk vine and young mangroves, pond apples and pop ash. The riverine plots appear to have muck soils while the upper tidal plots appear to have sandy soils.

In the late fall of 2003, Transect #7 had an extremely large number of cypress seedlings ranging from 5 cm to 7.6 cm in height. Germination of new seedlings continued well into the late spring. The dry season (December 2003 to May 2004) was very dry. Tides did not reach the entire transect during this period and the rains did not come until mid-July 2004. This dry period may have been advantageous for germination and early bald cypress seedling growth. During a visit in 2003, U.S.G.S. botanists, Helen Light and Melanie Darst., suggested that perhaps the stress of the salt may have made the trees more reproductively active. They also noted that the bald cypress trees on this site were probably younger than their counterparts in the riverine reaches of the river. Also in the riverine portion of the river, the cypress tree canopy was much taller and thicker. Therefore, less light maybe available for the development of an extensive subcanopy in the riverine reach. Duever et al. (1983) suggest that a good recruitment season for bald cypress may take place every 30 to 40 years. During a visit to Transect #7 in August 2004, many of the fall 2003 bald cypress seedlings were gone. Daily tides had returned to the interior of

the transect. Seedling death may have occurred because the seedlings were too short to survive the periods of tidal flooding (twice a day) or because of increased salinity. Some of these questions will be answered by the ongoing bald cypress seedling study.

Transect #9 is located at RM 6.5 on a peninsula near the JDSP (**Figure 3-14**). The hydrology of the floodplain in this area has been impacted by the placement of a trail that circles the peninsula. During extreme high tides, the trail acts as a barrier and traps saltwater behind in the wetland system. Elevations across Transect #9 range from 9.48 feet NGVD at the benchmark to a very low area (1.31 feet NGVD) located adjacent to the river (**Appendix C**). Between 50 and 70 meters from the upland a quite pronounced hammock area exists. Elevations in the hammock range from 1.95 feet NGVD to 2.05 feet NGVD and along the trail are 2.01 feet NGVD; the remaining areas in the floodplain are approximately 1.63 feet NGVD. Of the 20 plots on this transect 17 are lower tidal swamp (LTsw1 and LTsw2, **Appendix A, Table 1G**). The other 3 plots are upland, hammock, and LTmixed. The most prevalent species in the canopy, shrub and groundcover layers are red and white mangroves in the swamp areas and cabbage palm in the hammock areas (**Appendix B**). Pond apples in the canopy are rare; they are found predominately in the deeper swamp area at the back of the floodplains and had an average dbh of 7.2 cm. There is a noticeable difference between the distribution of red and white mangroves. White mangroves are dominant from the toe of the slope out to approximately 160 m. The remaining four plots (160 m to 200 m) are dominated by red mangrove. Leather fern dominates the shrub layer while water hyssop, leather fern and rubber vine dominate the groundcover. During a visit in August 2004, it was noted that the majority of the cabbage palms that had been recorded as alive in 2003 were now dead. The only cabbage palms remaining alive were associated with the trail and the hammock areas.

Historically, the canopy on Transect #9 was dominated by bald cypress trees; however, most of these trees are now dead. In his 1967 plant survey of this transect, Taylor Alexander reported live bald cypress at a frequency of 22.2 and a density of 0.39 (14 live and 28 dead). Red and white mangroves were at a frequency and density of 52.8/1.31 and 36.1/2.64 (47 red and 95 white). Alexander also reported the presence of several other freshwater species in small numbers including sawgrass (*Cladium jamaicense*), swamp lily, red bay, pop ash, red maple, and button bush. In a 1975 Jonathan Dickinson State Park survey of 100 bald cypress trees on the peninsular, 71 were dead, 21 were healthy and 8 were stressed. In our 2003 survey, there were no live cypress within Transect #9 and red and white mangroves were at a frequency and density of 47/5.79 and 100/12.32. In an April 2004 re-survey of bald cypress trees on the peninsula, 151 were dead, 7 were stressed and 3 were living. The three living bald cypress trees are directly adjacent to or on the elevated trail.



**Figure 3-14.** Location of Transect #9 on a Peninsula Near Jonathan Dickinson State Park.

## ANIMALS

The expansiveness and diversity of habitats occurring in or adjacent to the Loxahatchee River has attracted and continues to support many species of native animals. In 1965, 267 species of animals, consisting of 169 genera and 78 families, were observed in and along the Loxahatchee River and its estuary. The area surrounding the Northwest Fork is inhabited by numerous vertebrate species identified as endangered, threatened or of special concern by the Florida Fish and Wildlife Conservation Commission, or listed as threatened or endangered by the U.S. Fish and Wildlife Service. State and federally listed animals that occur in the watershed are shown in **Table 3-4**.

In addition, the entire Loxahatchee River has been designated by the U.S. Fish and Wildlife Service as a critical habitat for the West Indian manatee (1996). The manatee, an endangered aquatic mammal, frequents the Loxahatchee River estuary and river. Invertebrate and vertebrate aquatic animals are numerous in the marshes, lakes and streams in the river area. Freshwater fish include largemouth bass, speckled perch, bluegill, shellcracker, redbreast, warmouth, bowfin, gar, channel catfish and many species of minnows. Numerous turtles also live in and around the river. Saltwater fish include snook, tarpon, mullet, bluefish, jack, sheepshead, drum, sand perch, grouper, snapper and flounder. Mammals and birds are frequently encountered along the riverbank. The more commonly seen species include raccoon, opossum, whitetail deer, osprey, barred owl, egrets, herons and ibis.

Nuisance species include the Cuban treefrog (*Osteopilus septentrionalis*) and feral hog (*Sus scrofa*). The Cuban treefrog was limited to the Florida Keys and Miami-Dade County until the late 1960s. Since then, it has spread rapidly northward and has been reported north of St. Petersburg. The adult Cuban tree frog is larger than any other native tree frog in Florida and unfortunately readily eats the smaller native frogs. Feral hogs have spread widely across North America since their first introduction by DeSoto in 1539. They adversely impact the environment and agriculture through habitat degradation, predation competition on native species, and transmission of diseases to livestock and humans. In 2001, swine control assessments were conducted within Jonathan Dickinson State Park to gather information on abundance and distribution (Engeman et al., 2001). Although the swine control program reduced fresh damage indices, re-invasion was evident. Both Cuban tree frogs and feral hogs were evident on most of the vegetative transects.

Additional species, although not identified on the official lists compiled by the State of Florida, may be identified as being either endangered, threatened or of special concern by the Florida Committee on Rare and Endangered Plants and Animals. The threatened osprey often nests in dead cypress trees in the lower Northwest Fork. The great egret, the black-crowned night heron and the yellow-crowned night heron, classified as Species of Special Concern, are also found in the Loxahatchee River area.

The federally designated National Wild and Scenic portion of the Northwest Fork of the Loxahatchee River, a major part of which is located within Jonathan Dickinson State Park, contains 52 federal and state species that are endangered, threatened, or of special concern (23 animals and 29 plants). Those species having a federal designation found within this area include the alligator, indigo snake, scrub jay, bald eagle, wood stork, snail kite, manatee, four-petal paw paw, perforate lichen and Small's milkwort (FDEP, 1998).

**Table 3-4.** Threatened and Endangered Animals and Species of Special Concern in the Loxahatchee River Watershed.

Scientific Name	Common Name	FCREP <sup>a</sup>	FGFWFC <sup>b</sup>	USFWS <sup>c</sup>
MAMMALS				
<i>Peromyscus floridanus</i>	Florida mouse	T	SSC	
<i>Sciurus niger shermanii</i>	Sherman's fox squirrel	T	SSC	
<i>Trichechus manatus latirostris</i>	West Indian manatee	T	E	E
BIRDS				
<i>Ajaia ajaja</i>	Roseate spoonbill	R	SSC	
<i>Aphelocoma coerulescens</i>	Florida scrub jay	T	T	T
<i>Aramus guarauna</i>	Limpkin	SSC	SSC	
<i>Dendroica kirtlandii</i>	Kirtland's warbler	E	E	E
<i>Egretta caerulea</i>	Little blue heron	SSC	SSC	
<i>Egretta thula</i>	Snowy egret	SSC	SSC	
<i>Egretta tricolor</i>	Tricolored heron	SSC	SSC	
<i>Eudocimus albus</i>	White ibis	SSC	SSC	
<i>Falco peregrinus tundrius</i>	Arctic peregrine falcon	E	E	
<i>Grus canadensis pratensis</i>	Florida sandhill crane	T	T	
<i>Haliaeetus leucocephalus</i>	Bald eagle	T	T	T
<i>Mycteria americana</i>	Wood stork	E	E	E
<i>Pelecanus occidentalis</i>	Brown pelican		SSC	
<i>Picoides borealis</i>	Red-cockaded woodpecker	E	T	E
<i>Polyborus plancus audubonii</i>	Crested caracara		T	T
<i>Rostrhamus sociabilis</i>	Snail kite	E	E	E
<i>Speotyto cunicularia floridana</i>	Florida burrowing owl	SSC	SSC	
<i>Sterna antillarum</i>	Least tern	T	T	
FISH				
<i>Centropomus undecimalis</i>	Common snook		SSC	
AMPHIBIANS				
<i>Rana capito aesopus</i>	Gopher frog	T	SSC	
REPTILES				
<i>Alligator mississippiensis</i>	American alligator	SSC	SSC	T(S/A)
<i>Drymarchon corais couperi</i>	Eastern indigo snake	SSC	T	T
<i>Gopherus polyphemus</i>	Gopher tortoise	T	SSC	
<i>Pituophis melanoleucus</i>	Florida pine snake		SSC	

Data from Treasure Coast Regional Planning Council, 1999. Jonathan Dickinson State Park Unit Management Plan - State of Florida Department of Environmental Protection, February 2000.

<sup>a</sup> Florida Committee on Rare and Endangered Plants and Animals

<sup>b</sup> Florida Game and Freshwater Fish Commission

<sup>c</sup> United States Fish and Wildlife Service.

E=Endangered, R=Rare, T=Threatened, T(S/A)=Threatened/Similarity of Appearance, SSC=Species of Special Concern.

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## THE AQUATIC ECOSYSTEM

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Biological resources of the Loxahatchee River Estuary are greatly affected by freshwater inflows, tidal flows, and human activities. Various freshwater and marine organisms use these mixed estuarine areas during various times of their life cycles and are highly dependent on a specific salinity range in order to survive. The degree of salinity within a water body can be generally categorized into three types. Oligohaline waters have a low salinity (0.5-5 ppt), mesohaline waters have an intermediate salinity (5-18 ppt) and polyhaline waters have high salinity (18-30 ppt). Benthic organisms, since they are nonmobile, are also very sensitive to fluctuating salinities. In undisturbed estuaries in south Florida, mangrove forests, oyster bars and seagrass beds constitute major biological communities in brackish and saline environments. Numerous species of fishes and federally threatened species also depend on the Loxahatchee River Estuary. Thus, creating a flow scenario which balances the freshwater flow from the Northwest Fork of the Loxahatchee River with the tidal influx of seawater through the Jupiter Inlet will create an environment that is stable enough to maintain the desired species composition for each of these communities.

### OLIGOHALINE ECOZONE - LOW SALINITY ZONE

One of the important ecological functions of an estuary is the utilization of the low salinity zone (LSZ) at the head of the estuary. The LSZ serves as a nursery for larval and juvenile life stages of many important fish and shellfish (Pearse and Gunter, 1957; Gunter, 1961; Day et al., 1989). This critical habitat receives eggs, larvae and young from anadromous and catadromous fish and shellfish, estuarine spawners, and larvae spawned in the more saline lower estuary and ocean (Day et al., 1989). The relative magnitude of successful larval development and survival in the LSZ may be reflected in the magnitude of recruitment into the adult population (North and Houde, 2001).

The LSZ salinity range is typically defined as 0.5 to 5.0 ppt (oligohaline). However, this plan will extend the salinity range to 10 ppt since it has been demonstrated that this range is appropriate for studying fish larvae in an estuarine system (Holmes et al., 2000; North and Houde, 2001) and is often associated with the maximum turbidity known as the turbidity maximum (Jassby et al., 1995, North and Houde, 2001). Although salinity is not the only important variable defining the spatial extent of the LSZ nursery, salinity may act as a proxy variable for habitat characteristics which covary with salinity. The spatial extent of the LSZ in the Loxahatchee Estuary will be defined as the area upstream of the 10 ppt isohaline (**Figure 6-10**).

In general, the open waterway within the LSZ nursery area is an essential habitat for fish and shellfish larvae while the shallow shoreline and tributaries provides essential habitat for the juvenile fish and shellfish. **Table 3-5** lists the surface area of the Loxahatchee Estuary (in acres) and the length of shoreline (in feet) by River Mile segment. As the base flow increases, the cumulative area of waterway and cumulative length of shoreline of the LSZ habitat also increases. More detailed information will define the affects of different low-flow scenarios on the location and quantity of maximum turbidity in relation to larval utilization. The quality of LSZ shoreline may provide a more detailed evaluation of this habitat than the amount of habitat alone. For example, a shoreline composed of red mangroves acts as an important ecotone between the waterway and the floodplain wetlands and may have more habitat value than a seawall shoreline. A red mangrove shoreline with a shallow tributary may have even more habitat value than the mangrove shoreline alone. **Figure 3-6** shows the distribution of red mangroves and tributaries.

**Table 3-5.** Surface Area and Length of the Loxahatchee Estuary Oligohaline (Low Salinity) Ecozone from River Miles 4.0 to 10.5.

River Mile Segment	Area (Acres)	Cumulative Area (Acres)	Shoreline (ft)	Cumulative Shoreline (ft)
10.5 to 10	6.3	6.3	12,861	12,861
10 to 9	12.7	19.0	18,095	30,956
9 to 8	24.3	43.3	31,292	62,248
8 to 7	28.6	71.9	16,086	78,334
7 to 6	30.7	102.6	14,501	92,835
6 to 5	88.8	191.4	59,210	152,045
5 to 4	--	--	37,119	189,164

## MESOHALINE ECOZONE - OYSTERS

Estuarine areas with salinities between 10 and 20 ppt are defined as mesohaline regions. The key biological community that is most sensitive to impact is the oyster bar.

Oyster bars are important habitat providing extensive attachment areas for many organisms including oyster spat, mussels, tunicates, bryozoans, and barnacles (Woodward-Clyde International Americas, 1998). Oysters also play an important role in the estuarine food chain. Free-swimming oyster larvae are heavily preyed upon by planktivores, such as ctenophores, anemones, and larval fishes; and oyster spat are eaten by carnivorous worms and small crabs such as mud and juvenile blue crabs (Woodward-Clyde International Americas, 1998). Larger oyster spat and small adult oysters are consumed by blue crabs, stone crabs, whelks, conchs, oyster drills, boring clams, boring sponges, skates, rays and fishes such as black drum and redfish (Wells, 1961).

Periodic tidal exposure, sediments and water quality impact oysters and their associated fauna. Oyster spawning depends on salinities greater than 7.5 ppt and spat grow best at salinities above 12.5 ppt; the optimum salinity range for adult oysters is from 10 to 28 ppt and the lower salinities exclude marine predators (Sellers and Stanley, 1984). In the Loxahatchee River Estuary, oyster reefs grow mostly in intertidal and shallow subtidal areas. Oysters also grow on rip-rap, seawalls and bridge piers. Islands upstream of the Northwest Fork River delta (RM 4.5) are fringed with oysters growing on red mangrove roots. Reefs grow as point bars, usually on the downstream ends of the mangrove islands. In 1990, reefs were present in the Southwest and Northwest Forks but were rare in the North Fork of the Loxahatchee River. Oyster reefs in the Loxahatchee River embayment are small; contain mostly relict shells; and are associated with shoals, point-bars and mangrove islands (Law Environmental, Inc., 1991a).

Field observations in the Loxahatchee River Estuary (Law Environmental, Inc., 1991a) showed that oysters were smallest at upstream and downstream locations and largest in the central part of their range. This area is designated Class II, Shellfish Propagation and Harvesting, FDEP. The oyster populations in the polyhaline region of the Loxahatchee Estuary are limited to isolated shell clusters and accumulations on dock pilings. Most of the oyster populations in the Loxahatchee River Estuary are found in the Northwest Fork. In the Northwest Fork, the largest living oysters (standard length 80–90 millimeters) occurred between RM 4.0 and RM 6.0, where the average high tide surface water salinities were between 7 ppt and 22 ppt, and ranged from about 2 ppt to 28 ppt. The river delta (“S-Bar”), located at approximately RM 4.5, played a

controlling role in upriver salinities and was the most active oyster ground (Law Environmental, Inc., 1991a).

## **POLYHALINE ECOZONE - SEAGRASSES**

Estuarine areas with salinities between 18 ppt and 30 ppt are defined as polyhaline regions. For this plan, the section of the Loxahatchee River Estuary from the Jupiter Inlet (RM 0.0), through the Embayment (RM 2.0), to RM 4.0 is considered to be within the polyhaline ecozone. Key biological communities in the Loxahatchee Estuary that could potentially be impacted by upstream restoration activities include mangrove forests, oyster bars, and seagrass beds. Since most of the mangrove and oyster populations are found upstream of the polyhaline zone these community types are only briefly discussed below but are addressed in greater detail in other sections of the plan.

Seagrass beds are one of the most productive and important estuarine communities. They provide food for bacteria and microscopic animals at the base of a complex food web, as well as, food for larger organisms such as green sea turtles (*Chelonia mydas*) and manatees (*Trichechus manatus*). Seagrass beds offer a refuge and nursery ground for numerous commercially and recreationally valuable shrimp, fishes and crabs and their prey (Zieman, 1982; Phillips, 1984; Thayer et al., 1984; Kenworthy et al., 1988; Zieman and Zieman, 1989).

Wading birds frequent seagrass beds at low tides to feed on fish that use the seagrass canopy and root/rhizome mat for shelter (Sogard et al., 1989). Migratory waterfowl and diving birds also regularly feed in and over seagrass beds. Some of the invertebrate fauna associated with seagrass beds include gastropods, star fishes, sea urchins, sea cucumbers, pink shrimp, and spiny lobster. Seagrass beds are visited or inhabited by numerous fish species. They provide nursery habitat for recreationally and commercially important drums (Sciaenidae), sea bass (Serranidae), porgies (Sparidae), grunts (Pomadasyidae), snappers (Lutjanidae), and mojarras (Gerridae) (Odum and McIvor, 1991).

Seagrass beds are also known to enhance water quality. They bind shallow underwater sediments with their roots and rhizomes. The leafy canopy baffles waves and currents (Fonseca et al., 1983; Fonseca and Fisher, 1986; Fonseca, 1989; Fonseca and Cahalan, 1992). The baffling inhibits resuspension of fine particles and traps sediments in the water column, providing water column cleansing (Ward et al., 1984). Additionally, seagrasses and associated epiphytes and macroalgae take up dissolved nutrients.

It is generally accepted that if healthy seagrass beds are present, then a diverse and productive faunal community will also be present. Biological productivity and diversity in many estuarine systems is dependent upon healthy seagrass beds. Numerous studies have shown high densities and diversities of animals in seagrass beds (Gilmore, 1995; Lewis, 1984; Thayer et al., 1984; Virnstein et al., 1983).

All seven seagrass species that occur in South Florida are found within the Loxahatchee Estuary. Six species of seagrasses are currently found in the polyhaline region of the estuary. The seventh species, widgeon grass (*Ruppia maritima*), is present upstream in the oligohaline region near RM 6.5 (Loxahatchee River District, 2004). The six species of seagrass found within the polyhaline region are: shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), turtle grass (*Thalassia testudinum*), paddle grass (*Halophila decipiens*), star grass (*Halophila engelmannii*), and Johnson's seagrass (*Halophila johnsonii*). The dominant seagrass species present in the polyhaline region of the estuary is shoal grass.

This plan focuses on restoration efforts that will change the freshwater inflows to the Northwest Fork of the Loxahatchee River and may potentially impact the salinity regime in the estuary. An understanding of the salinity tolerances of the seagrass species within the estuary is needed to help evaluate potential impacts of proposed upstream restoration efforts on the downstream resources.

A literature review was conducted for the SFWMD to evaluate salinity tolerances of seagrasses found in the St. Lucie Estuary (Woodward-Clyde International, 1998). Although none of the studies found through the literature review were conducted on plants from the Loxahatchee Estuary, the studies did include all of the species found in the Loxahatchee. These species-specific literature values provide the basis for the Loxahatchee seagrass/salinity evaluation presented in this plan.

The referenced literature review suggests normal and optimal salinity tolerance ranges for all seven seagrass species. Widgeon grass and shoal grass have the widest salinity tolerance ranges: 0 – 45 psu and 5-55 psu, respectively. Optimal (no stress) conditions for growth and survival apparently occur between 5 – 15 psu for widgeon grass and 24-36 psu for shoal grass. More narrow salinity tolerance ranges are suggested for turtle grass (16-50 psu) and manatee grass (17-44 psu). The optimal ranges suggested for these two species are 25 – 35 psu for turtle grass and 24 – 36 psu for manatee grass.

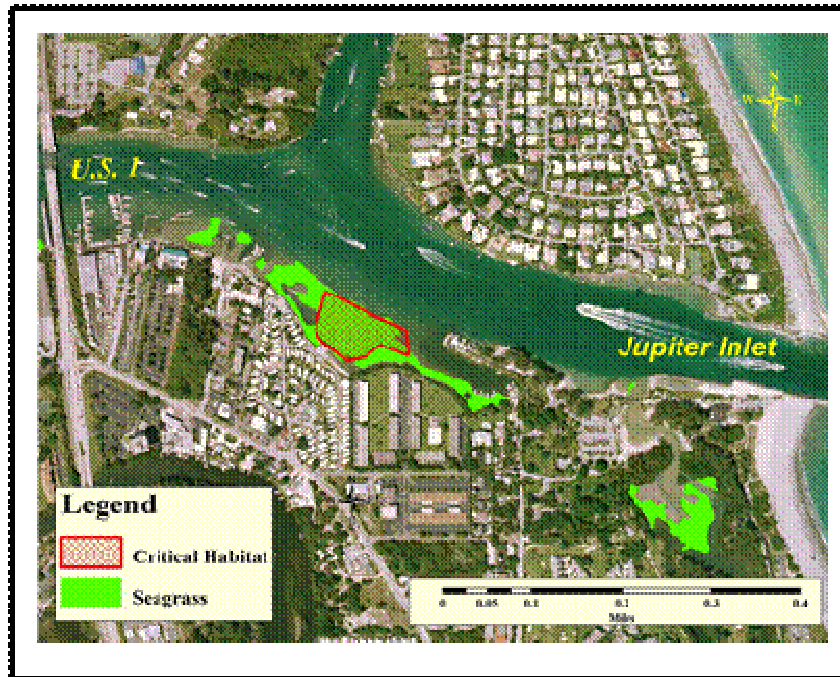
The *Halophila* species have the least well-documented salinity ranges of the seven seagrass species found in the Loxahatchee River, but based on information provided in the literature review, the following normal tolerance ranges are suggested: Paddle grass (22 – 38 psu), Star grass (10-40 psu), and Johnson's seagrass (15-43 psu). Apparent optimal salinity conditions are paddle grass (27-34 psu), star grass (25-35 psu), and Johnson's seagrass (25-35 psu).

Additional studies were reviewed to evaluate salinity ranges that may cause stress (reduced growth or increased mortality) to the species found in the Loxahatchee Estuary. Information was found for stressful salinities for shoal grass, manatee grass, turtle grass, and Johnson's seagrass. A study by Doering et al. (2002) showed that very little growth occurred in shoal grass between 6 and 12 psu. Another study (McMahan, 1968) indicated that blade mortality occurred in shoal grass below 6 psu. Two separate laboratory studies documented impacts to manatee grass at 15 psu. In one experiment, blade densities declined in plants exposed to 15 psu for 26 days (SFWMD, 1999 unpublished). In another experiment leaf extension rates declined in plants exposed to 15 psu for 14 days (Lirman and Cropper, 2003). Studies of turtle grass found limited growth between 16 and 19 psu and a decrease in photosynthesis at 18 psu (Woodward-Clyde, 1998). Doering and Chamberlain (2000) found growth parameters in turtle grass were negatively impacted between 6 and 12 psu. Finally, although very little salinity tolerance information is available for the *Halophila* species, Dawes et al. (1989) conducted a laboratory study that indicated that blade mortality occurred when Johnson's seagrass was exposed to 5 psu for 3 days.

Johnson's seagrass occurs throughout the polyhaline region of the Loxahatchee Estuary (Loxahatchee River District, 2004). It is the only seagrass species listed as "threatened" by the Federal Government. Johnson's seagrass is listed as "threatened" because of its limited geographic distribution; it has only been found along the Florida east coast from Sebastian Inlet to northern Biscayne Bay. On April 5, 2000 (65 Federal Register 17786), the National Marine Fisheries Service (NMFS) published a final rule designating critical habitat for Johnson's seagrass. One of 10 sites identified as critical habitat is located near the Jupiter Inlet in the Loxahatchee Estuary (**Figure 3-15**). The designation as "critical habitat" means that the Federal government has determined that the designated area is vital to the conservation of the listed species. Any proposals to alter flow conditions in the Northwest Fork to the extent that they may



impact the local population of Johnson's seagrass will have to be reviewed and approved by the NMFS.



**Figure 3-15.** Critical Habitat for Johnson's Seagrass Within the Loxahatchee Estuary.

Another Federally listed species that occurs within the Loxahatchee Estuary is the West Indian manatee, *Trichechus manatus*. This endangered species feeds on seagrasses and frequents the Loxahatchee Estuary. Changes in freshwater delivery could potentially contribute to changes in distribution or abundance of seagrass which could impact this endangered species. As with Johnson's seagrass, any proposed flow modifications that could potentially impact endangered species will have to be reviewed and approved by the NMFS.

## BENTHIC MACROFAUNA

Benthic organisms are important as consumers of plankton and detritus in filtering the water column, and as food for bottom-feeding fish. Benthic macroinvertebrates are sensitive to subtle changes in water quality. The diversity and abundance of these organisms in the ecosystem make them good biological markers for investigating long-term changes in this estuarine environment. Unlike plankton or fishes, their limited mobility makes them reliable indicators of the overall health of a system.

Various surveys of macrofauna have been conducted in the Loxahatchee Estuary (McPherson et al., 1984; Strom and Rudolph, 1990; Law Environmental, Inc., 1991a; Dent et al., 1998). McPherson et al. (1984) studied fouling organisms in the estuary and noted that two of eight barnacle species occurred only in marine salinities, while other species occurred in lower salinities. Only one species occurred as far upstream as the JDSP. The overall diversity, density and growth of fouling communities are greater in high salinity areas, greater before the summer-wet season and higher after tropical storms. Strom and Rudolph (1990) observed that

representatives of brackish water fauna occurred as far upstream as the Trapper Nelson site (RM 10.5), although most of the species at this location were typical of freshwater environments.

Samples collected by Law Environmental, Inc. (1991a) from oyster reef communities in the estuary contained representatives of 41 invertebrate taxa from seven phyla. Analyses of these data indicated that four taxa had broad distributions along the river and occurred upriver to the limit of their survey within JDSP. Almost a third of the taxa were marine species, requiring high salinities that occurred no farther upstream than the oyster reef at the mouth of the Southwest Fork.

The Wildpine Ecological Laboratory, Loxahatchee River District, performed quantitative infaunal sampling at nine estuarine stations between 1992 and 1999. Sampling occurred twice a year, once during the dry season (February-March) and once during the wet season (September-November). The locations of five of the nine estuarine stations are presented in **Figure 3-16**. Preliminary results (Dent et al., 1998) found 410 invertebrate species in the estuary and adjacent waters. The five estuarine stations sampled, overall, contained fewer taxa than the four stations located in more marine waters. Estuarine stations contained a larger proportion of crustaceans (44%) than annelids (33%) or mollusks (11%), whereas stations in more marine waters contained a predominance of annelids (58%), about 30 percent crustaceans and 7 percent mollusks. Initial analyses of these data, and comparison with data from other studies suggest that this estuarine invertebrate community shows seasonal changes in species composition and short-term changes due to specific rainfall or discharge events. The major phyla collected at the three stations are shown in **Table 3-6**.

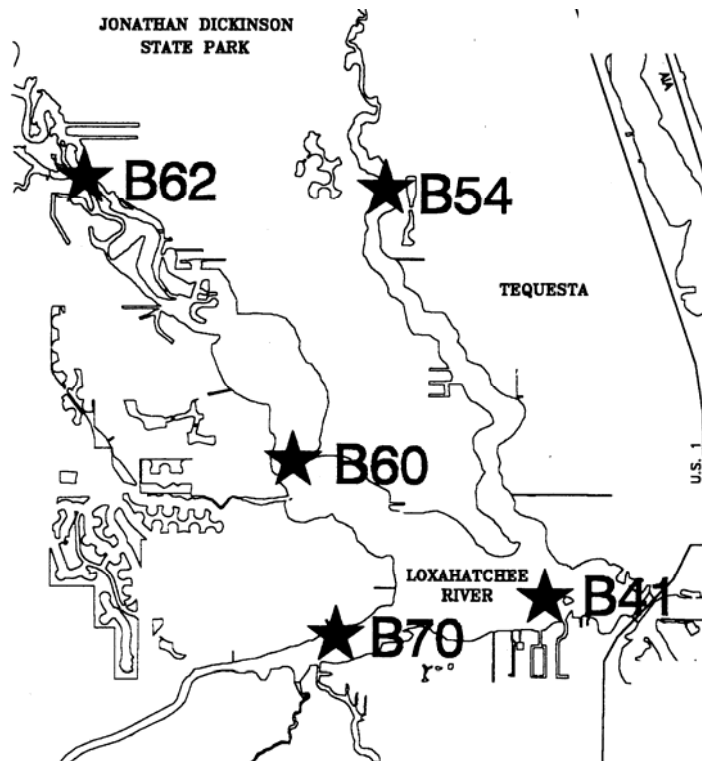
The South Florida Water Management District (SFWMD) also conducted routine benthic macroinvertebrate sampling between February 1985 and March 1988. Samples were collected every other month at five sites on the Loxahatchee River.

Currently, under a contract with the District, the Smithsonian Marine Station Ft. Pierce is conducting data analysis of the two above-mentioned data sets to determine if there has been a change in the benthic macroinvertebrates between 1985 and 1999.

**Table 3-6.** Summary of Benthic Taxa Present in the Loxahatchee Estuary.

Station	Abundance (total mean)	Annelids	Crustaceans	Mollusks	Other	Total # of Species
<b>B41</b>	2812	54	36	64	4	73
<b>B60</b>	1599	39	41	15	5	85
<b>B70</b>	2795	61	22	11	6	113
<b>B62</b>	1913	17	48	13	22	76
<b>B54</b>	1605	44	42	4	10	66

Data from Dent et al., 1998.



**Figure 3-16.** Location of Loxahatchee Estuary Macroinvertebrate Sampling Stations Used by Dent et al., 1998.

## FISHES

Several studies have examined fish communities within the Loxahatchee River, including Christensen (1965), Synder (1984) and Hedgepeth (2001). Salinity studies have been conducted by Birnhak (1974), Rodis (1973), Chiu (1975) and Russell and McPherson (1984). The Loxahatchee River Environmental Control District has ongoing studies of fishes and salinity as well as invertebrates and seagrasses. Studies of fishes indicate that a significant relationship exists between community composition and salinity on the Loxahatchee River. The upstream area of the river (above RM 9.0) is characterized by freshwater species; the lower portion (from the Jupiter Inlet to RM 5.0) is characterized by marine and estuarine species; and the remaining midstream section (between RM 5.0 and RM 9.0) is characterized by freshwater and estuarine species.

Data from a study of fishes collected from the Loxahatchee Estuary during 1982-1983 (Hedgepeth, personal communication; Hedgepeth et al., 2001) indicate that the season of the year, salinity and availability of habitat affect the abundance, distribution and diversity of fishes in the estuary. The dominant fishes in the Loxahatchee Estuary are listed in **Table 3-7**.

**Table 3-7.** Relative Abundance and Ranking of the Most Abundant Fishes in the Loxahatchee Estuary During 1982–1983 (Hedgepeth et al., 2001).

Species	Specimens Rank	Biomass Rank	Appearance Rank	Sum of Ranks	Overall Rank
<i>Dasyatis americana</i>	16	15	16	47	19.3
<i>Harengula humeralis</i>	8	14	16	38	12.5
<i>Harengula jaguana</i>	2	3	16	21	7
<i>Jenkinsia lamprotaenia</i>	15	16	16	47	19.3
<i>Sardinella aurita</i>	9	12	16	37	11
<b>Anchoa hepsetus</b>	<b>1</b>	<b>2</b>	<b>13</b>	<b>16</b>	<b>3</b>
<i>Anchoa lyolepis</i>	6	16	16	38	12.5
<b>Anchoa michilli</b>	<b>3</b>	<b>8</b>	<b>7</b>	<b>18</b>	<b>5</b>
<i>Synodus foetens</i>	16	16	15	47	19.3
<i>Strongylura notata</i>	16	9	6	31	10.5
<i>Strongylura timucu</i>	16	16	11	43	15
<i>Trachinotus falcatus</i>	16	16	12	44	16
<i>Diapterus auratus</i>	16	13	9.5	38.5	13
<b>Eucinostomus argenteus</b>	<b>4</b>	<b>4</b>	<b>1</b>	<b>9</b>	<b>1</b>
<b>Eucinostomus gula</b>	<b>10</b>	<b>5</b>	<b>2</b>	<b>17</b>	<b>4</b>
<i>Eucinostomus jonesi</i>	13	16	16	45	17
<i>Gerres cinereus</i>	14	16	16	46	18.5
<i>Archosargus probatocephalus</i>	16	16	14	46	18.5
<i>Lagodon rhomboides</i>	12	10	5	27	9
<b>Leiostomus xanthurus</b>	<b>5</b>	<b>1</b>	<b>9.5</b>	<b>15.5</b>	<b>2</b>
<i>Mugil cephalus</i>	7	7	8	22	8
<i>Mugil curema</i>	11	6	3	20	6
<i>Sphyraena barracuda</i>	16	11	4	31	10.5
<i>Spheroides testudineus</i>	16	16	10	42	14

**Bold text** indicates the most abundant species.

The numbers of anchovies (*Anchoa* spp.) and herrings (*Harengula* spp.) peaked during the month of February, while the numbers of sciaenids (*Leiostomus xanthurus*), anchovies, herrings and mojarras (*Eucinostomus* spp.) peaked in July. These peaks reflected spawning periods for these groups. The seagrass beds of the embayment, the lower North Fork and lower Southwest Fork tend to support the highest number of species and individuals (**Table 3-8**). Abundance and diversity were also higher at sites where average salinities were above 25 ppt. At sites where salinities averaged 5 ppt. or lower, the number of species declined markedly. The most abundant species were anchovies (*Anchoa* spp.); mojarras (*Eucinostomus* spp.); and spot (*Leiostomus xanthurus*).

**Table 3-8.** Numbers of Fish Collected in Loxahatchee Estuary as a Function of Salinity (1982–1983).

Station Location	# of Individuals	# of Species	Salinity (ppt)		
			Mean	Minimum	Maximum
Embayment Area	185,936	102	24.6	3.0	35.0
Lower North Fork	20,405	62	21.3	6.0	35.0
Upper North Fork	945	30	3.7	0.0	22.0
Mid-Northwest Fork	911	30	4.6	0.0	19.0
Upper Northwest Fork	869	40	0.4	0.0	4.0
Lower Southwest Fork	49,416	68	9.8	0.0	27.0
Total for all Stations	258,482	144	15.6	0.0	35.0

Source: Hedgepeth et al., 2001

## THREATENED OR SPECIES OF SPECIAL CONCERN

### Manatees (*Trichechus manatus*)

The Florida manatee (West Indian manatee) is an important marine mammal that lives in or seasonally visits the Loxahatchee River system (Packard, 1981). Manatees are federally protected by the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. They are also protected by the Florida Manatee Sanctuary Act of 1978, which establishes the entire state as a refuge and sanctuary for manatees.

The Loxahatchee River (Northwest and Southwest Forks) is considered a high priority water body because this area has a well documented history of manatee use. Manatees are found primarily in the Southwest Fork near S-46, the lower North Fork, Jupiter Inlet (river mouth) and residential canals. Nearby Jupiter Sound has also been identified as a seasonally important manatee feeding ground. The largest concentrations of manatees occur in October, January, and December (Law, 1991b). Manatees and their calves have been observed apparently drinking fresh water at the S-46 structure. This area may also be an important nursery area and mating behavior has been observed in this vicinity (Law, 1991b). Although manatees can often be seen skimming fresh water off the surface and congregating at spillways and other freshwater sites, ingestion of freshwater in this manner is not a requirement (USFWS, 1996). In general, manatees avoid areas with high boat traffic and tend to migrate upstream into Jonathan Dickinson State Park during rough weather. Concerns have been raised that hydrologic alteration of freshwater flows delivered to the estuary could potentially contribute to changes in the distribution or abundance of submerged aquatic plant communities, a reduction in water quality and/or a reduction in adequate levels of warm water that manatees require.

### Opossum Pipefish (*Microphis brachyurus lineatus*)

The opossum pipefish was added to the candidate species list in 1997 (USDC, 1998). The predominant areas in which there is concern for this pipefish is in the Indian River Lagoon of Florida. NMFS initiated a status review of this species in 1998 to determine if listing under the ESA is warranted.

The opossum pipefish is a circumtropical species; breeding adults are only found in freshwater associated with certain vegetation such as panic grass (*Panicum* spp.) and smart weed (*Polygonum* spp.). Brooding male opossum pipefish have been captured in tributaries to the

Indian River Lagoon, Florida, during all months except January and February. Predictable breeding adult populations are limited to tributaries of the Indian River Lagoon, the Sebastian, St. Lucie, and Loxahatchee rivers thus the adult populations are restricted to the east coast of Florida adjacent to the warm Florida Current. These areas receive freshwater from inland and upland sources as part of an extensive coastal flood control system.

The main reason that the opossum pipefish is becoming very rare is that its habitat is disappearing as a result of several factors. First, continuous human settlement limits the areas in which these pipefish live. The rapid and continual growth of the coastal human population displaces pipefish habitat. Because these pipefish need access to very specific vegetation types and to freshwater, there are few places they can migrate to. Furthermore, migration is limited because of flood control structures which block rivers and canals that could provide pipefish habitat. Lastly, herbicide treatment, which also destroys vegetated pipefish habitat, provides a potential threat for this limited Florida population.

### **Johnson's Seagrass (*Halophila Johnsonii*)**

Johnson's seagrass was listed as a federally endangered species in September, 1998 (USDC, 2000). It has a very limited distribution and it is one of the least abundant seagrasses within its range. It plays a major role in the viability of benthic resources and has been documented as a food source for the endangered manatees. The species is only known to reproduce asexually and may be limited in distribution because of this characteristic.

Johnson's seagrass has a disjunct and patchy distribution along the east coast of Florida from central Biscayne Bay to Sebastian Inlet. The largest patches have been documented inside Lake Worth Inlet. The southernmost distribution is reported to be in the vicinity of Virginia Key in Biscayne Bay. The species has been found in coarse sand and muddy substrates and in areas of turbid waters and high tidal currents.

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# Chapter 4:

## Valued Ecosystem Components (VECs) and Performance Measures (PMs)

The SFWMD supports the application of a resource-based management strategy similar to the Valued Ecosystem Component (VEC) approach developed by the U.S. Environmental Protection Agency (USEPA, 1987). The VECs or biological indicators are described as species or communities that relay a complex message of ecological community composition and health in a simplified and useful manner (USEPA, 2000). Thus, an indicator species or community should reflect the biological, chemical and physical attributes of ecological conditions within a designated habitat. By adopting this strategy, management objectives are attained by providing a suitable hydrological and water quality environment for VECs. In turn, these VECs sustain an important ecological or water resource function by providing food, living space, refugia, and foraging sites for other desirable species in the ecosystem. This approach assumes that environmental conditions suitable for VECs will also be suitable for other desirable species and that the enhancement of VECs will lead to enhancement of other species.

Formulation of the Northwest Fork of Loxahatchee River ecosystem restoration plan is also based on the VEC approach. The objective of this chapter is to identify VECs for each of the ecological segments in the Northwest Fork and the Loxahatchee Estuary. Performance Measures (PMs) representing characteristic regimes of hydrology or salinity in the ecosystems are also identified for each of the VECs to evaluate the performance of restoration alternatives. These PMs are measurable and can be quantitatively or qualitatively related to the health of VECs.

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### THE FLOODPLAIN ECOSYSTEM

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In this section the proposed community-based Valued Ecosystem Components (VECs) and performance measures (PMs) for the floodplain ecosystem will be discussed. A floodplain VEC is identified in this assessment as one of the critical units that characterizes or defines a particular floodplain forest community type. Dufrêne and Legendre (1997) calculate indicator species values by uses categorical environmental variables, levels of disturbance, experimental treatments, presence-absence of target species or habitat types. Thus, a perfect indicator species should be one that is always present or faithful to the identified group or habitat type. In our assessment of VECs for the major floodplain forest types, abundance and frequency of the primary canopy tree species within a forest community type were used. Three distinct reaches (riverine, upper tidal, and lower tidal) and four major forest community types (swamp, bottomland hardwood, hammock, and upland) have been identified on the floodplains of the Northwest Fork of the Loxahatchee River. The dominant canopy species listed in **Table 4-1** best reflect the native plant species that should be present for each forest community type. The proposed PMs will gauge the success of restoration and enhancement efforts and provide flow management guidelines for floodplain hydroperiods and salinity environment.

**Table 4-1.** Summary of Hydrological Conditions, Soil Textures, and Dominant Canopy Species for the Floodplain Forest Communities in the Loxahatchee River and Its Major Tributaries.

Forest Type	Typical Hydrological Conditions	Primary Soil Type	Dominant Canopy Species
Oak/pine	Flooded average of every 10 years; soils dry quickly after floods recede	Sand	<i>Pinus elliottii</i> <i>Quercus myrtifolia</i>
Hydric Hammock	Flooded average of 2 months (30-60 days)	Sand	<i>Sabal palmetto</i>
Mesic Hammock	Rarely inundated; soils elevated and dry quickly after floods recede	Sand	<i>Quercus virginiana</i>
Rblh3 Rblh2	Flooded average of every 3 years, sometimes for durations of 1-2 months or more; soils dry quickly after floods recede	Sand	<i>Quercus laurifolia</i> <i>Chrysobalanus icaco</i> <i>Ilex cassine</i> <i>Carya aquatica</i> <i>Persea borbonia</i>
Rblh1	Flooded average of 1 month every year; soils remain saturated another month	Sand, loam, clay	<i>Acer rubrum</i> <i>Cephalanthus occidentalis</i> <i>Persea palustris</i> <i>Salix caroliniana</i>
Rsw1 Rsw2	Flooded average 4-7 months every year; soils remain saturated another 5 months	Clay, muck	<i>Taxodium distichum</i> <i>Fraxinus caroliniana</i>
Rmix	Flooded 2 to 3 months every year	Sand	<i>Taxodium distichum</i> <i>Sabal palmetto</i>
UTmix	Flooded 2 to 3 months every year; soils dry quickly in some areas and remain continuously saturated in others	Loam, muck, sand	<i>Laguncularia racemosa</i> <i>Annona glabra</i> <i>Acer rubrum</i> <i>Salix caroliniana</i> <i>Cephalanthus occidentalis</i> <i>Taxodium distichum</i>
UTsw3	Flooded monthly by high tides or high river flows	Muck	<i>Fraxinus caroliniana</i> <i>Rhizophora mangle</i>
UTsw2 UTsw1	Flooded daily by high tides from 9-11 months of the year most soils continuously saturated		<i>Laguncularia racemosa</i> <i>Annona glabra</i>
Hydric Hammock	Flooded every 1-2 years by either storm surge or high river flows, high water table, surface soils on higher elevations dry quickly and soils continuously saturated in lower areas	Muck, sand	<i>Sabal palmetto</i> <i>Chrysobalanus icaco</i> <i>Persea borbonia</i> <i>Quercus virginiana</i> <i>Myrica cerifera</i>
LTmix	Flooded daily or several times a month by high tides except in isolated areas; soils continuously saturated except for the interior of hammocks	Muck	<i>Laguncularia racemosa</i> <i>Sabal palmetto</i> <i>Rhizophora mangle</i> <i>Annona glabra</i>
LTsw2	Flooded daily for 9 months every year	Muck	<i>Laguncularia racemosa</i> <i>Rhizophora mangle</i> <i>Annona glabra</i>
LTsw1	Flooded daily every year	Muck	<i>Rhizophora mangle</i> <i>Laguncularia racemosa</i>
Data obtained from USGS, 2002.			

## RIVERINE FLOODPLAIN VEC: SWAMP AND HYDRIC HAMMOCK CANOPY COMMUNITIES

### Justification

Swamp and hydric hammock canopy communities are identified as the VEC communities for the riverine floodplain ecosystem. Within the riverine floodplain forests, floodplain communities are predominately **bald cypress** and **bald cypress/pop ash** swamps with mixed areas of low bottomland hardwood and hammock. Hydric hammock communities are dominated by **cabbage palm** with some **live oak**, **wax myrtle**, and **red bay** (Table 4-1). Cypress swamps and hydric hammocks are unique wetland forest types that are native and predominant in the riverine floodplain. These forest types characteristically support the riverine floodplain ecosystem.

Low bottomland hardwood communities dominated by **red maple**, **buttonbush**, **swamp bay**, and **Carolina willow**, and high bottomland hardwood dominated by **water hickory**, **laurel oak**, **dahoon holly** and **cocoplum** are also present in the riverine floodplain. In impacted areas where large trees were historically logged, it appears that bald cypress is being replaced by pop ash and bottomland hardwood species that require shorter hydroperiods and are faster growing. Very few bald cypress seedlings or saplings are noted in the shrub and groundcover of the riverine reach. This may be due reduced light availability, low nutrients, or the younger age of the existing canopy trees. It is reasonably assumed that if hydrological conditions are improved for the targeted swamp and hydric hammock VEC species then the appropriate shrub and groundcover species and bottomland hardwood species would eventually be protected as well.

Regarding the enhancement and restoration of the floodplain forest communities, the native Carolina willow (*Salix caroliniana*) has been considered as a nuisance species. Under the right conditions it can grow as a tree or shrub and form thickets. It prefers swamps, stream banks, sand and gravel bars, ditches and wet thickets (Dressler et al., 1987). The native shrub Virginia willow (*Itea virginica*) also has a preference for swamps and wet forests and was present in the 2003 vegetation transects. Within Jonathan Dickinson State Park, these two willows appear to have invaded the freshwater marsh systems along the back side of the Atlantic Ridge and the North Fork of the Loxahatchee River. Therefore, the distribution of these two species needs to be carefully monitored.

### Distribution

Cypress swamps are typically found in the low floor of the floodplain immediately adjacent to the river. Hydric hammocks are generally found on higher elevations (about 1.5 - 3 feet higher than swamps) that do not receive regular tidal inundation or frequent river flooding. **Chapter 5** provides detailed descriptions of the distribution of these communities in each of the vegetation transects in the riverine floodplain.

### Performance Measures

Wetland hydroperiod in the riverine floodplain, which is closely related with flows over the Lainhart Dam, is used as a performance measure for the riverine floodplain. **Table 4-2** provides a summary of suggested or observed hydroperiods of major floodplain plant community types reported in the literature. Observations of hydroperiod duration by wetland community type appear to be longer in south Florida than those observed in other regions, including northern

Florida. Based on the literature, swamp wetland communities require 270-360 days (9-12 months) of inundation per year and hydric hammock communities require 30-60 days (1-2 months) of inundation per year (**Table 4-2**). However, the Northwest Fork of the Loxahatchee River is characterized by short periods of flooding followed by extensive periods of low discharge. Hydroperiods for swamps and hydric hammocks under such an environment should be shorter than what is suggested in **Table 4-2**.

Based on available data and our observations of the riverine floodplain ecosystem, we propose that wet season water levels in the Northwest Fork will allow for brief inundation of hydric hammocks in the range from 2 inches to 6 inches above the ground surface elevation. Such inundations shall not be continuous for over a month and the total number of days of such inundations during a year shall be less than 30 on the average. The water level in the floodplain shall also provide a hydroperiod of 4 to 8 months inundation in a year to support a healthy swamp community in the riverine floodplain. During the dry season, the water level shall be in a range from 0 to 1.5 feet below the mean ground elevation for the floodplain swamp area.

These proposed hydroperiods for swamp and hydric hammock areas are supported by other studies in rivers similar to the Northwest Fork. Light et al. (2002) has suggested 4-7 months per year for nontidal (riverine) floodplain swamps. Darst et al. (2003) indicates that hydric hammocks in a riverine floodplain do not receive regular tidal inundation or frequent river flooding, but have a high water table and are briefly inundated by severe storm several times a decade. More detailed analysis of flow over the Lainhart Dam and floodplain inundation in the riverine floodplain are presented in **Chapter 5**.

**Table 4-2.** Hydroperiods of Major Wetland Plant Community Types.

Plant Community Type	Wet Season Water Depth (inches)	Inundation Duration (days/year)
Mesic Flatwood	0-2	≤30
Scrubby Flatwood	Below ground	0
Dry Prairie	0-2	0-30
Sandhill	Below ground	0
Scrub	Below ground	0
Mesic Hammock	0-2	0-60
Wet Flatwood	2-6	30-60
Hydric Hammock	2-6	30-60
Depression Marsh	12-24	180-300
Slough	>36	230-360
Wet Prairie	6-16	60-180
Strand Swamp	18-36	210-300
Floodplain Swamp	18-30	270-360
Dome Swamp	12-24	210-300
Mangroves	—	Daily tidal
Maritime Hammock	—	10-45

Sources: Drew and Schomer (1984); Duever et al. (1984); Vince et al. (1989); Abrahamson and Harnett (1990); Myers (1990); Mitsch and Gosselink (1993); David (1996); FDEP (2003a)

## TIDAL FLOODPLAIN VECS: SWAMP COMMUNITIES

### Justification

The dominant canopy species for the upper and lower tidal reaches should include predominantly **bald cypress** and **pond apple** in the swamp areas and **cabbage palm** in the hydric hammock areas because of the low elevations of the tidal floodplains. **Pop ash**, **red maple**, **Carolina willow** and other freshwater canopy species should increase their recruitment in areas where there are higher elevations, hummocks, old cypress stumps, or fallen logs (**Table 4-1**). As these freshwater species slowly return to the canopy, mangroves would become restricted to the shrub layer as currently exhibited in the floodplains of lower Kitching Creek.

Floodplain vegetation along the tidal reaches of the Northwest Fork of the Loxahatchee River has changed over the past century from a bald cypress swamp to a red and white mangrove swamp because of salt water intrusion. Protection and restoration of freshwater vegetation along the Northwest Fork requires an understanding of the relationship between the floodplain swamp forest community composition and exposure to salinity. In addition, characterization of the succession processes between freshwater and salt-tolerant species will aid in developing management guidelines and strategies to support restoration goals. Successful restoration of the freshwater swamp forest communities will require decades or even centuries before major canopy changes are clearly visible within the upper and lower tidal floodplains of the Northwest Fork. Therefore, we are proposing both short-term and long-term performance measures. The short-term performance measure will examine changes in the species composition within the shrub and groundcover layers. The long-term performance measure will examine the recruitment (germination) and growth of the target canopy species.

### Distribution

Upper tidal floodplain communities are dominated by mixed swamps and hydric hammocks (**Table 4-1**). Although bottomland hardwood indicator species are present, distinct areas of bottomland hardwood were not present, probably due to the lack of topographical change and low existing elevations. Hydric hammock and bottomland hardwood species have adapted to this habitat by growing on hummocks, cypress stumps and fallen logs. Canopy in the upper tidal plots was comprised of pond apple and red and white mangroves. Bald cypress and pond apple seedlings and saplings were noted in the shrub and ground cover vegetation of the upper tidal reach. The restoration and enhancement goals for the upper tidal reach are to promote the increase in abundance and distribution of freshwater forest species in the canopy, shrub and groundcover components of the floodplain community and reduce the spread of mangroves and exotic plant species.

In the lower tidal floodplain communities, the canopy was comprised of mostly red and white mangrove depending on elevation. There was no evidence of freshwater seedling/sapling production in the lower tidal areas with the exception of pond apple, which appears to be salt tolerant. Therefore, restoration and enhancement goals will focus on reducing salt concentrations and increasing freshwater inundation to promote healthier sustainable habitats within the swamp and hydric hammock areas. Of particular concern in the tidal reaches is the distribution of white mangrove. This species appears to overlap the preferred elevations of pond apple communities. Most white mangroves are single trunk trees with limited branches while most pond apples are multi-trunk trees. These differences in growth habits appear to be directed at maximizing light availability for white mangrove and maximizing root structure for pond apple. On several

transects, white mangroves appear to be shading out the older pond apple communities, although the stunted growth of pond apples may also be due to increases in the salinity of water and soil.

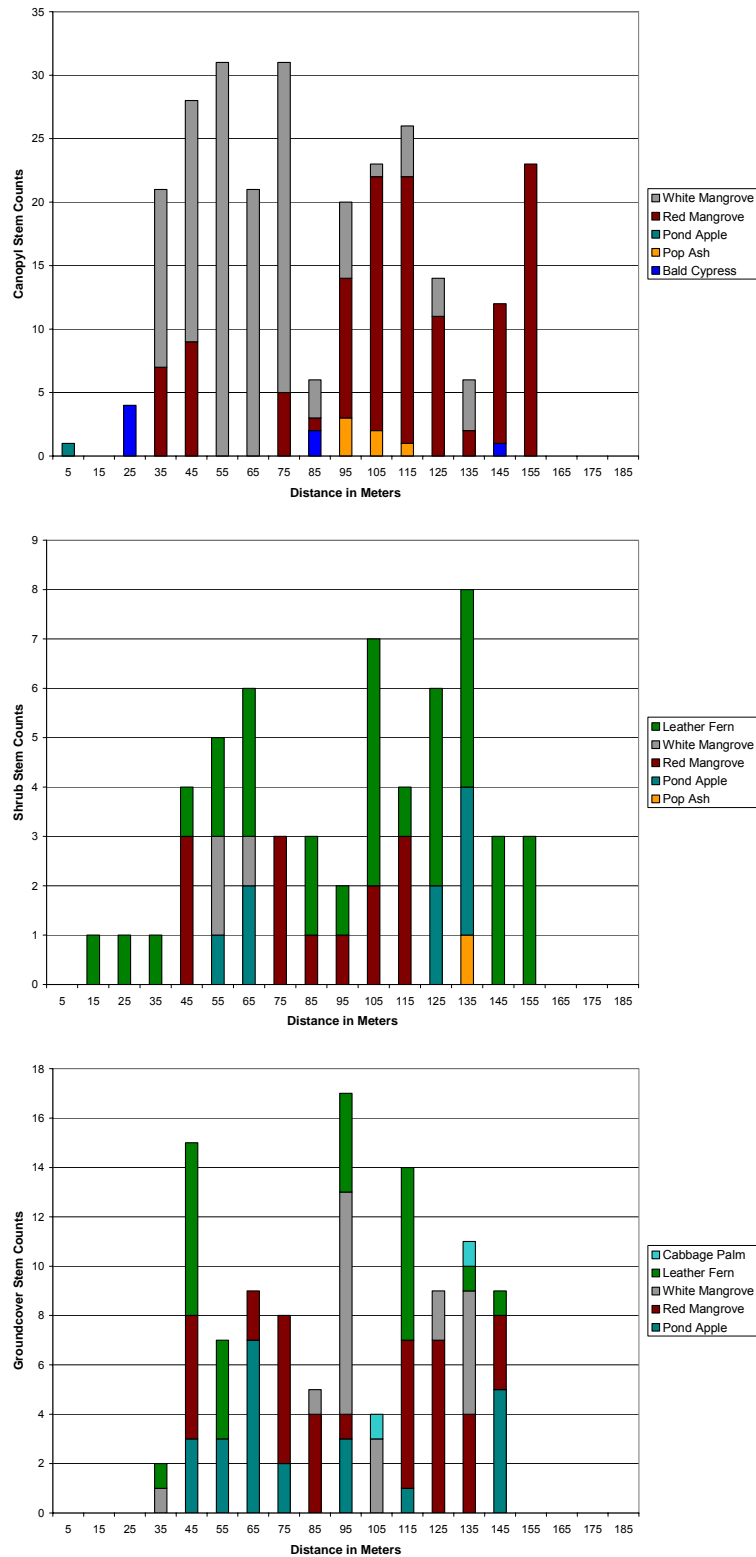
The 2003 Vegetative Transect Study provides a baseline evaluation of the target canopy, shrub, and groundcover species present in the upper and lower tidal reaches of the Northwest Fork of the Loxahatchee River. **Figures 4-1, 4-2 and 4-3** provide a summary of the abundance of target canopy, shrub and groundcover species as they occur across the three belt transects from uplands to the riverbed. Note that bald cypress only appears in the canopy of Transects #6 and #7 whereas pop ash appears in both the canopy and shrub layers of Transects #6 and #7. Pond apples appear in all three vegetative layers of all three tidal transects. It is also important to determine the baseline distribution of red and white mangrove along the belt transects in order to track future distribution and abundance and its effect on competition with the freshwater species. Red and white mangroves are present on all three transects. As the preferred freshwater forest species within the tidal reaches are restored, it is important to note that mangroves communities can survive in freshwater environments (Odum et al., 1982). Therefore, we would not expect to see a decline in the number of mangroves if salinities were lowered and freshwater flows were increased across the floodplains. However, reductions in mangrove populations have occurred as a result of freezing and/or damage from hurricanes.

## Performance Measures

One of the major concerns regarding restoration in the tidal floodplains of the Northwest Fork of the Loxahatchee River is the effect of saltwater intrusion on seed production, germination and seedling/sapling/adult growth and survival of bald cypress, other freshwater deciduous trees, and shrub and groundcover species. The performance measure for the tidal floodplain is proposed to be a characteristic salinity regime in the Northwest Fork that is closely associated with the recruitment and health of these swamp species in the floodplain.

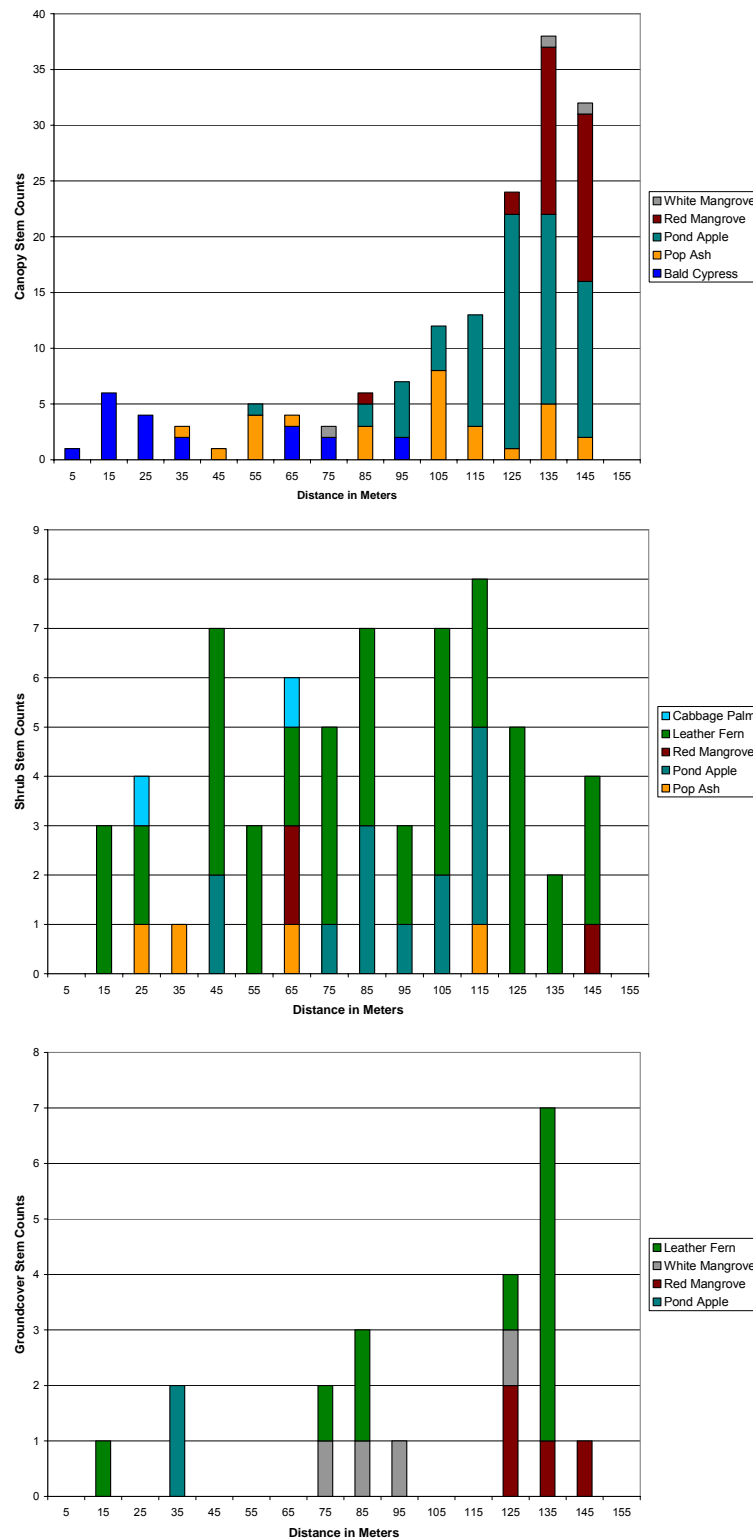
### **CHARACTERISTIC SALINITY REGIMEN**

The characteristic salinity regimen at a site in the Northwest Fork is defined by a ratio of the duration of all salinity events ( $D_s$ ) over the duration of between these salinity events ( $D_b$ ) over a long period of time such as over 30 years. The  $D_s/D_b$  ratio integrates salinity exposure duration, magnitude and recovery time between salinity events into a single numerical factor. In **Chapter 6**, we present the long-term salinity data that are predicted by a salinity management model. SFWMD staff concluded that the salinity regimen ratio  $D_s/D_b$  (using 1 ppt threshold) showed a highly significant ( $p < 0.0001$ ) negative correlation ( $r^2 = 0.997$ ) with distance from the Jupiter Inlet (**Figure 4-4**). As the site moves upstream, the  $D_s/D_b$  ratio approaches zero since fewer salinity events occur. In contrast, the  $D_s/D_b$  ratio exceeds one and rapidly increases downstream as the magnitude and duration of each salinity event increases, and the time between salinity events decreases. Use of the  $D_s/D_b$  ratio affords a closer “fit” to salinity conditions than would have been provided by the use of standard descriptive statistics. SFWMD staff further found that the abundance and diversity of vegetation along the river corridor of the Northwest Fork is closely correlated to the salinity ratio, which provides a reasonable estimate of the status of the vegetation community at a site (Zahina, 2004). In **Chapter 7**, we demonstrate how increasing fresh water inflows into the Northwest Fork in the dry season would change this salinity characteristic regimen, and ultimately change the tidal floodplain vegetation.

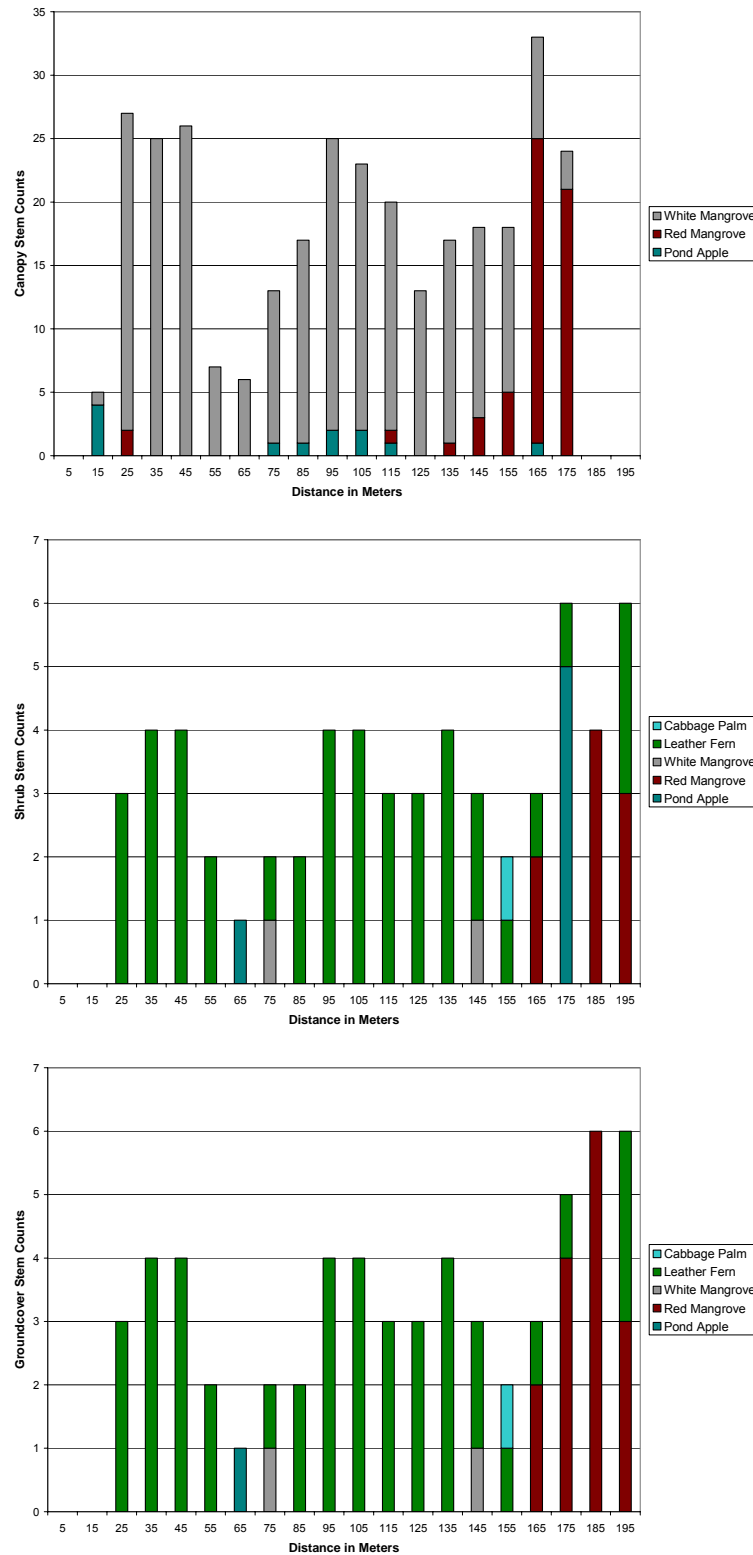


**Figure 4-1.** Select Canopy, Shrub, and Groundcover Species by Distance (in m) from the Uplands for Transect #6: Upper Tidal Reach.

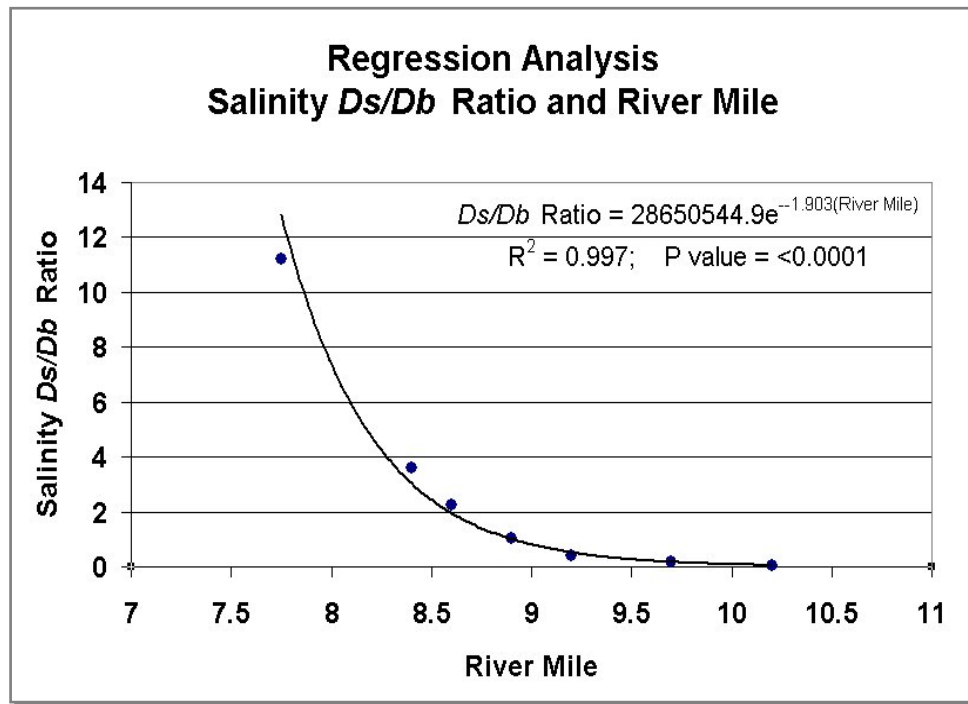




**Figure 4-2.** Select Canopy, Shrub, and Groundcover Species by Distance (in m) from the Uplands for Transect #7: Upper Tidal Reach.



**Figure 4-3.** Select Canopy, Shrub, and Groundcover Species by Distance (in m) from the Uplands for Transect #9: Lower Tidal Reach.



**Figure 4-4.** Correlation Between Salinity Event Ratio *Ds/Db* (> 1 ppt) and River Mile.

#### **BALD CYPRESS SALINITY TOLERANCE AND THRESHOLD SALINITY**

Bald cypress is the dominant canopy species in this floodplain swamp community; therefore, intra-seasonal biological and inter-seasonal hydrological needs to support seed production, germination and growth of bald cypress should be considered. From a reproductive standpoint, bald cypress is monoecious: both male and female strobili are produced on the same tree from buds formed during the previous year. Pollen is generally shed from the male cones in the spring and the seeds mature in the female cone scales between fall and early winter. Seeds are spread primarily by small animals and floodwaters. Germination takes place on the surface of the soil or moss. Seeds will not germinate under water but may remain viable for 30 months under water. A 1- to 3-month period of saturated soil conditions (but not flooded) is required for germination. Complete submergence of seedlings tends to hinder growth and prolonged submergence kills seedlings. Bald cypress can also reproduce vegetatively by producing sprouts (U.S. Department of Agriculture, 1974).

In general, the literature suggests that bald cypress seedlings and adult trees are moderately salt tolerant. The growth of bald cypress seedlings is affected by a number of factors including soil type, soil moisture, nutrients present in flood waters, percent shading, crowding by competing vegetation, salt water, and duration and frequency of flooding. The combination of flooding and salinity is more detrimental to survival of bald cypress seedlings than the effect of either stress alone. Wicker et al. (1981) concluded that bald cypress wetlands are limited to areas where salinity does not exceed 2 ppt for more than 50% of the time that the trees are exposed to inundation or soil saturation. Allen et al. (1994) and Pezeshki et al. (1995) found that bald cypress seedlings exhibited intraspecific variation in tolerance to a combination of flooding and salinity

stress. Allen et al. (1994) noted that 3 months of combined flood and salinity stress led to considerable decreases in leaf, stem, and root biomass at 4 ppt and a notable decrease in root density index between the 4 ppt and 6 ppt treatments. Myers et al. (1995) found that 1- to 4-year-old seedlings planted in a frequently flooded marsh thrived despite a nearly constant groundwater salinity of 2.8 ppt. Conner and Askew (1992) observed that 6-month old seedlings were extremely susceptible to short term (0-5 days) saltwater flooding (30 ppt) and survival percentages declined with more than one day of salt water flooding. They also noted that at salinity levels above 4 ppt, the proportion of biomass partitioned to roots decreased. This was attributed to an ion imbalance causing severe disruption of root metabolic functions. Krauss et al. (1998) examined the effect of salinity levels on bald cypress germination. The germination percentages at salinity levels of 0 ppt, 2 ppt, 4 ppt, and 6 ppt were 26.3%, 22.9%, 15.4% and 10.2%, respectively.

In conclusion, the available information in the literature does not suggest a single threshold salinity value for bald cypress. However, it is evident that as salinity levels approach 2 ppt and as the length of exposure increases bald cypress seed germination and seedling growth is reduced. Because of the tidal influence on salinity concentrations throughout a day, the salinity threshold used to calculate the  $D_s/D_b$  ratio in **Chapter 7** is 1 ppt.

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## THE ESTUARINE ECOSYSTEM

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Restoration scenarios being evaluated in this plan include increasing freshwater discharges during the dry season to the Northwest Fork of the Loxahatchee River. These additional discharges may alter the salinity regime in the estuary, potentially impacting current healthy, estuarine communities. Oysters and seagrasses have been selected as the VECs for evaluating potential changes in the salinity ranges (and inflow ranges) in the Loxahatchee Estuary because, they

- are widely accepted as indicators of healthy estuarine systems;
- are currently present in the estuary;
- were present historically (post inlet construction) in the estuary;
- are sessile organisms that can not migrate away from unacceptable salinities; and,
- have fairly well-documented salinity ranges.

In addition, fish larvae and juvenile snook in the low salinity zone are also proposed as a VEC for evaluation in the plan.

### LOW SALINITY ZONE VEC: FISH LARVAE AND JUVENILE FISH

#### Justification

Several factors appear to make the low salinity zone (LSZ) a viable nursery. The LSZ may provide optimal salinity and temperature conditions for growth and development of larvae and juveniles (Pearce and Gunter, 1957; Gunter, 1961; North and Houde, 2001). Low salinity itself and/or the high turbidity often characteristic of this zone may provide a refuge from predation

(Turner and Chadwick, 1972; Chesney, 1989) and the dissolved nutrients and detritus associated with freshwater input make the LSZ highly productive.

Freshwater inflows enhance detrital and phytoplankton/periphyton based food chains in the LSZ which benefits larval and juvenile fish (Holmes et al., 2000; North and Houde, 2001; Turner and Chadwick, 1972). The presence of an adequate food supply, favorable environmental conditions, and/or a refuge from predation ensures successful development and survival (North and Houde, 2001). For example, in the stratified upper Chesapeake Bay, high flows may create a well-defined low salinity entrapment zone with an organic rich turbidity maximum that supports an abundance of zooplankton prey (North and Houde, 2001). Fish larvae are retained in an optimal salinity environment that provides a rich food supply, and a refuge from predation through high turbidity (North and Houde, 2001). During low flow, the entrapment zone is weaker and more diffuse. The turbidity maximum is less well defined and relatively depleted in organic matter. Production of zooplankton prey is limited and larvae may experience suboptimal salinities owing to reduced retention capacity (North and Houde, 2001). In contrast, in the well-mixed estuary of the Parker River, a phytoplankton bloom in the oligohaline zone (0.5 to 5.0 ppt) during low flow conditions supports a productive pelagic food chain. A long hydraulic residence time allows phytoplankton and zooplankton to accumulate in the upper estuarine LSZ. During higher flow conditions, the bloom and accompanying larvae are flushed down the estuary (Holmes et al., 2000). It is believed that the Loxahatchee Estuary experiences these same types of relationships that influence the survival of year class larvae and therefore need to be evaluated as various levels of dry season inflows are considered.

Of these fish species found in the LSZ, the common snook, *Centropomus undecimalis*, is one of the most protected sport fishes within the state of Florida and has historically been a major management concern in the Loxahatchee Estuary. Previous work (Taylor et al., 1998; Lowerre-Barbieri et al., 2003; and James Whittington, FWCC, personal communication) has demonstrated the common snook spawns near Jupiter Inlet in high salinity waters through the summer, peaking late summer, August and September. The juvenile phase, however, utilizes shallow water habitat in the LSZ of the Northwest Fork where salinity can vary significantly with inflows and its microhabitat can be predicted based on past research in the Loxahatchee River and the region (Gilmore et al., 1982, 1985, 1986, 1987, 1994; Lewis et al., 1985; McMichael et al., 1989; Peters et al., 1998; Peterson and Gilmore, 1991; Taylor et al., 1998, 2000). For this reason, documenting the salinity and habitat requirements of juvenile snook would be an appropriate way to evaluate the affects of varying low flows during November and December.

## Distribution

To determine the distribution and abundance of fish and shellfish larvae and juvenile snook in the waterway of the LSZ, a sampling program was conducted. Larvae were sampled, during peak utilization, weekly for three weeks in May and June 2004 from the Boy Scout Camp Dock to the Trapper Nelson's historical site. Three sample site locations were documented with GIS coordinates and sampled at night with duplicate 2-minute plankton tows (505 microns). Plankton samples were preserved in buffered 10% formalin for later identification and quantitative assessment. Water quality collected at each site included dissolved oxygen, salinity, water temperature, and secchi depth. During the same sampling time interval for larvae, in May and June, the presence of spawning fishes was surveyed in the estuary by using a hydrophone during a 2-minute drift and recording acoustic mating calls unique to a species. Additional recordings were made at known spawning sites of the common snook near and within the Jupiter Inlet. Juvenile snook (< 150 mm Standard Length) collections were made at sites resembling previously isolated snook settlement locations studies over the past 30 years in the Indian River Lagoon

system and its freshwater tributaries (Gilmore et al., 1982, 1985, 1986, 1987, 1994; Lewis et al., 1985; McMichael et al., 1989; Peters et al., 1998; Peterson and Gilmore, 1991; Taylor et al., 1998, 2000). Six sites in the Northwest Fork were selected for juvenile snook sampling for a single day trip, including capture, identification, and measurement and tagging. These settlement sites were chosen from locations in the LSZ where small streams enter the main river or where sand bars emerge from the bank.

The results of this sampling program indicate that the highest densities of fish larvae were found within the LSZ where salinity levels were between 2 ppt and 8 ppt. The dominant species are anchovies and gobies. This finding is supported by several years of fish larvae sampling completed in the 1980s by District staff (unpublished) in the Northwest Fork. Juvenile snook were distributed throughout the Northwest Fork at specific microhabitats. They were evenly distributed within a wide spectrum of salinity ranges (0-16 ppt). A more detailed discussion of this sampling program is provided in **Chapter 7** for fish larvae and in **Appendix H**.

## Performance Measures

Since the volume of water in the LSZ of the Northwest Fork of the Loxahatchee River is relatively small, small increases of inflows to the Northwest Fork directly increases the LSZ spatial extent and overlapping salinity features utilized as a nursery that may affect the distribution and abundance of larval and juvenile life stages of fish and shellfish. Based on the SFWMD investigations, salinity levels ranging from 2 ppt to 8 ppt can be used as a performance measure for fish larvae in the LSZ. Juvenile snook have definite microhabitat preferences which include being near tributaries with sand bottoms. The distribution of juvenile snook did not appear to be related to salinity. Therefore, the availability of the preferred microhabitat is for more important to juvenile snook than is salinity. The use of salinity as a performance measure of juvenile snook abundance seems to have little utility.

## MESOHALINE ZONE VEC: OYSTERS

### Justification

Estuaries are transitional environments in which salinity varies between freshwater and seawater (Moyle and Cech, 1982) and the amounts of freshwater runoff and tidal flushing largely determine the biological character of an estuary (McPherson et al., 1984). One important biological component of the Florida estuaries is the distribution and health of the eastern oyster (*Crassostrea virginica*). This species of oyster thrives best in estuarine waters with a yearly average salinity between 10 ppt and 20 ppt (Woodward-Clyde, 1998). Therefore, since adult oysters are sessile, estuarine locations that experience these favorable salinities may accommodate oyster health. Changes in freshwater runoff characteristics from the watershed could alter the salinity gradient in the estuary; thus the location of healthy oyster populations will reflect the 10 ppt to 20 ppt salinity levels.

Oyster bars provide significant habitat structure and value within the benthic environment in the Loxahatchee Estuary; those areas of the estuary without oyster bars have limited structure. Oyster reefs provide extensive attachment area for numerous organisms including oyster spat, mussels, tunicates, bryozoans, and barnacles (Woodward-Clyde, 1998). Several studies have demonstrated the high species richness of oyster bars (Pearse and Wharton, 1938; Frey, 1946; Wells, 1961; Bahr and Lanier, 1981).

Oysters play an important role in the estuarine food chain and filtering the water. Free-swimming oyster larvae are frequently preyed upon by planktivores, such as ctenophores, anemones, and larval fishes; and spat are eaten by carnivorous worms and small crabs (Woodward-Clyde, 1998). Larger spat and small adult oysters are often consumed by blue crabs, stone crabs, whelks, skates, rays and fishes such as black drum and redfish (Wells, 1961). Loosanoff (1946) indicated that oysters filter water at a rate of about 1500 times its body volume per hour. Maintaining a healthy, sustainable oyster population would help water quality and provide important habitat within the system. In order to maintain a healthy population of oysters in the middle Loxahatchee estuary, the average annual salinity should be near 15 ppt; exposure to salinities below 10 ppt can be stressful to oysters. The specific salinity tolerances of oysters related to stress, harm, and death are presented as a Performance Measure.

## Distribution

Early European settlers called the receiving water body of the Loxahatchee watershed “Jupiter River” which was frequently a freshwater river that did not support oyster populations. Periodically, however, the Jupiter Barrier Island was breached as a result of storm events, creating passes that allowed sea water to intrude into the river and create an estuarine environment. During these times, the embayment supported a large oyster population. These passes would naturally fill in, returning the river to a freshwater environment uninhabitable by oysters. In the late 1940s, the U.S. Army Corps of Engineers dredged and stabilized the Jupiter Inlet and the Intracoastal Waterway that connected the Loxahatchee River with the Indian River and Lake Worth Lagoons. This dramatic alteration in landscape enabled estuarine conditions to occur on a regular basis in the Loxahatchee River Estuary. Salinity conditions at that time favored the development of oyster reefs near the mouth of the estuary at the FECRR trestle. As these reefs developed through the years they reduced navigation, tidal communication and water quality within the estuary. The oyster reefs were considered by local government and citizens to be a major cause of the deteriorating condition of the river. Several studies in the mid-1970s were conducted to address the potential increase in saltwater intrusion and tidal currents into the Northwest Fork if the oyster reefs were removed from the trestle area (Christensen, 1973; Chiu, 1975; Hill, 1977). A mathematical salinity model predicted that with the removal of the oyster reefs, the slack high tide salinity would move 260 feet to 600 feet further upstream in the Northwest Fork; however, the oyster reefs were removed by 1978.

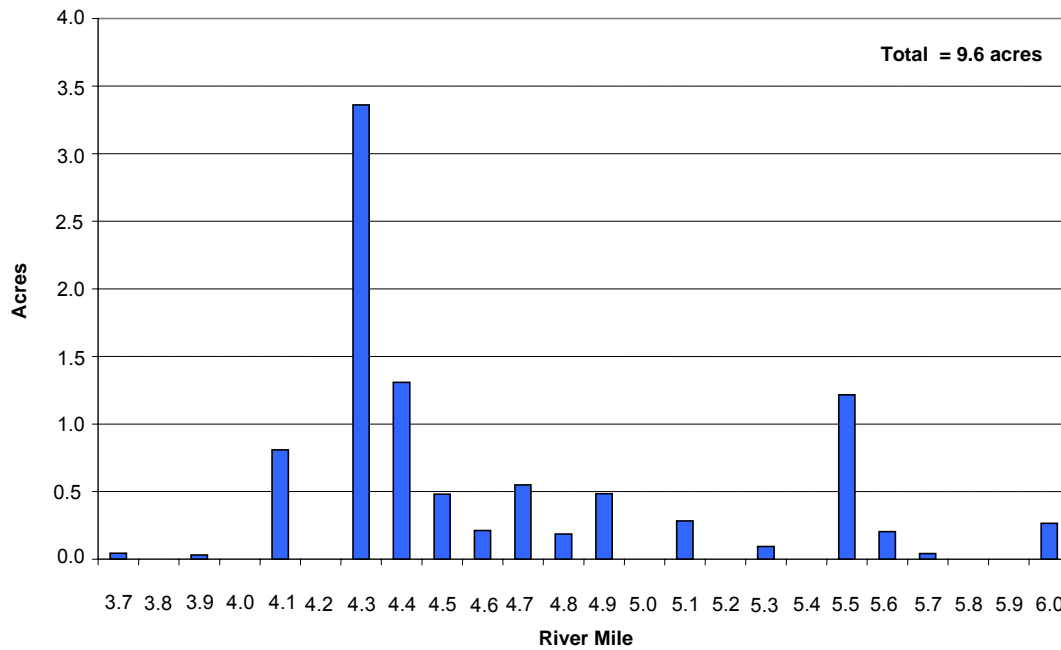
After the removal of the oyster reefs, the U.S. Geological Survey conducted field investigations in 1980-1981 that provided information on bathymetry, hydrology, and benthic sediment and biota. A map resulting from this effort revealed nine small, live oyster reefs in the embayment (McPherson, 1982) with a total area less than 1.5 acres. Another survey in 1985 mapped oysters in the embayment and suggested a decrease in area of live oyster reefs from 1981 observations (Klemm and Vare, 1985). No effort was made in either of these studies to determine the presence of adult oysters in the Northwest Fork of the Loxahatchee River. In 1990 there was an investigation of oyster distribution and size throughout the Loxahatchee River which included the Northwest Fork (Law Environmental, Inc., 1990). In 1990, the embayment was regularly experiencing salinities greater than 25 ppt. The oyster reefs present were small and mostly dead due to decreased food and increases in predation and disease. Based on field observations (Law Environmental, Inc., 1990), the oysters were smallest at their upstream and downstream locations and largest (80–90 mm) in the central part of their range in the Northwest Fork, which extended from the trestle bridge to about River Mile 6.5. The largest living oysters occurred between RM 4.0 and RM 6.0 which indicated that this area experienced the most favorable conditions for oysters in 1990. In contrast, large dead oyster shells were found in the embayment, as remnants of a former lower salinity environment.

In October 2003, under a contract with the District, the Loxahatchee River Control District conducted an oyster survey in Loxahatchee River and Estuary (Wild Pine Ecological Laboratory, 2004). The live oyster reefs surveyed were defined as areas having at least five live oysters per square meter. The area of concern for this document, however, is in the Northwest Fork as shown in **Figure 4-5**, where 9.6 acres of oysters were mapped between RM 4.0 to RM 6.0 (**Figure 4-6**). The density of live and recently perished oysters as well as their total length (grouped into three classes: < 5 cm, 5-10 cm, and > 10 cm) were collected at four locations in the Northwest Fork (**Figure 4-7**). The majority of the oysters (76%) were < 5 cm in length, 23% were between 5 and 10 cm long, and only 0.2% greater than 10 cm long. The highest density of oysters and largest area of reefs occurred at RM 4.5 (900 oysters/square meter). Density decreased upstream to about 690 oysters/square meter at RM 5.5 and to 410 oysters/square meter at RM 6.0.

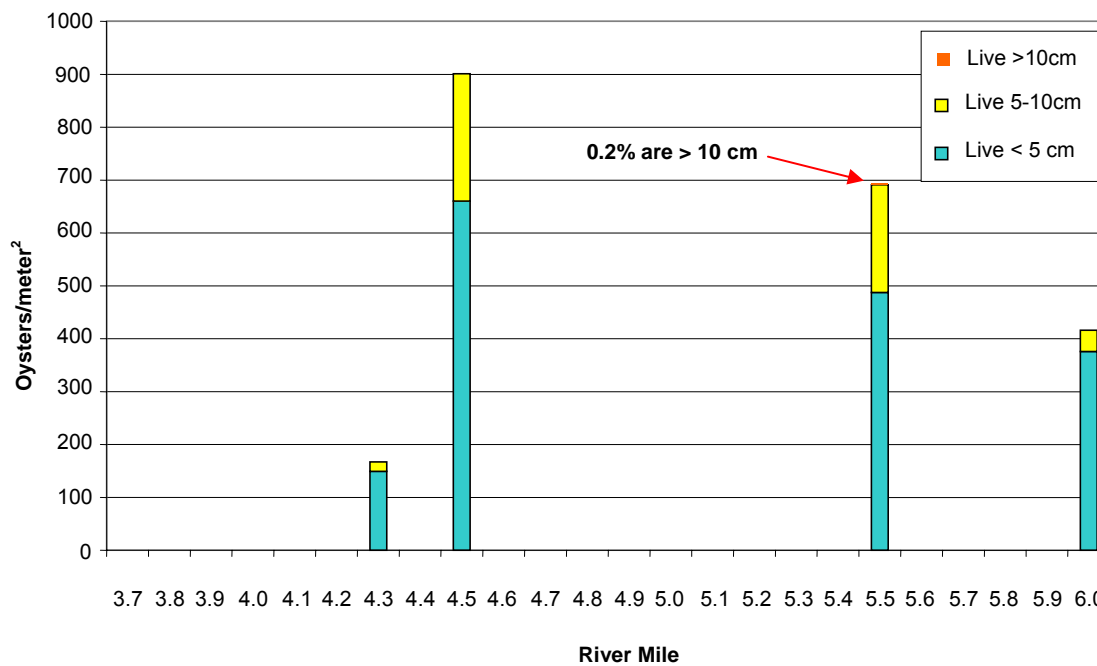




**Figure 4-5.** Oyster Bed Distribution (yellow) in the Northwest Fork of Loxahatchee River Conducted in 2003. Monitoring Stations are Marked as Red Dots.



**Figure 4-6.** Oyster Acreage in the Northwest Fork of the Loxahatchee River Estuary.



**Figure 4-7.** Oyster Distribution in the Northwest Fork of the Loxahatchee River Estuary.

## Performance Measures

The salinity tolerance of oysters (*Crassostrea virginica*) between RM 4.1 and RM 5.9 is identified as a PM for the Plan. **Table 4-3** defines the stress level of the life history of oysters (eggs, larvae, spat, and adults) in relation to salinity and the duration of exposure. The evaluation methods used for the performance measures are described in **Chapter 7**.

Suitable habitat for the eastern oyster within an estuarine salinity gradient from freshwater to seawater is predominately influenced by salinity, food supply, availability of appropriate substrate (cultch), disease and predation. A combination of these factors results in sparse densities or absence of oysters in the upper and lower estuary, and high densities (near 1000 oysters/m<sup>2</sup>) in the middle estuary. Low oyster densities in the upper estuary occur due to frequent exposure to harmful or lethal salinities while low densities in the outer estuary result from limited food supply, high predation and disease (*Perkinsus marinus*). The most suitable habitat, with the highest densities of oysters, is in the middle estuary having a salinity range from about 10 ppt to 20 ppt. This salinity range is favorable for reproduction, growth, and food supply and the reduced presence of disease and predators is well documented at these salinities. The major focus of this evaluation for the Loxahatchee Estuary is on the region from the inner estuary, where oyster density is lowest (near RM 6.0), to the middle estuary (near RM 4.0) where oyster density is highest. Limiting the evaluation to this region minimizes the need to quantitatively describe the affects of predation and disease on oyster density in the lower estuary which is not included in this evaluation. Of all the factors influencing oyster density, salinity or salinity as a surrogate, is used to explain a major portion of the effects freshwater inflows on the oyster population. In order to describe these effects, an understanding of salinity tolerances of oysters at each life stage is necessary.

**Table 4-3** shows salinity values and exposure durations for four oyster life stages (eggs, larvae, spat, and adult) that cause oyster stress, harm, and mortality. Most of these salinity values and durations were obtained from the literature where were determined for oyster populations for areas other than Florida, however, an effort was made to include recent salinity affects on juvenile and adult oysters from the Caloosahatchee and St. Lucie estuaries, Florida (Volety et al., 2003; Roesijadi, 2004). A recent study of oyster life history in the St. Lucie estuary, immediately north of the Loxahatchee estuary (Wilson et al., 2004) was utilized for the timing of life stages in the Loxahatchee estuary. In that study, a major spawn occurred in the spring of the year (March and April) with no documented spawning in the fall. Therefore, a distinctive year class of oysters is revealed in **Table 4-3** where larval presence from March to May follows egg development and spawning, and spat and juvenile oysters are present from April to August. Since oysters in south Florida usually live 2 to 3 years, adults are present throughout the year. Oysters are known to spawn in south Florida from March to September, however, Wilson's work shows that if protracted spawning occurs, the sampling device (oyster shell hanger) does not document significant spat recruitment beyond the spring.

Information compiled in **Table 4-3** was used to develop a model of salinity tolerances for each life stage during their presence in the estuary (Haunert and Konyha, 2004). To reduce the variability of salinity, a daily mean salinity value is used as input. Salinities were calculated at locations where oysters were known to occur for the base case study and alternative inflows using salinity models described elsewhere in this document. Initial model runs were made using daily salinities that occurred two years prior to the field survey of Loxahatchee oysters in November 2003 which documented the horizontal distribution of oyster bars and the size class and density of oysters. Based on the sizes and the approximate growth rates of local oysters, it was assumed that all live oysters were less than two years old. The purpose of these model runs

was to ascertain the frequency and magnitude of stress, harm, and mortality for each life stage throughout the oyster's inner and middle estuary distribution (RM 4 to RM 6) during the last two years. The frequency and magnitude of stressful conditions at each location was paired with the density of oysters at that location to determine the quantitative relationship between these factors. Once this relationship was documented, it was added to the model to allow long term (35 years) simulations of oyster distribution and densities for the base case and alternative inflow scenarios. This method would therefore permit a comparison with the base case that quantitatively reveals if the suitability of the oyster habitat increased or decreased with the flow alternatives.

**Table 4-3.** Salinity Tolerances During the Life History of the American Oyster.

Life Stage	Salinity (ppt)	Duration (days)	J	F	M	A	M	J	J	A	S	O	N	D	Reference
<b>Eggs</b>			X	X	X	X									Wilson et al., 2004
Harm	7.5 - 10.0	1													Burrell, 1986
Mortality	0.0 - 7.5	1													Burrell, 1986
<b>Larvae</b>					X	X	X								Wilson et al., 2004
Stress	10.0 - 12.0	1													Loosanoff, 1965; Davis, 1958
Harm	0.0 - 10.0	1													Davis 1958
Mortality	0.0 - 10.0	14													Davis, 1958
<b>Spat &amp; Juveniles</b>						X	X	X	X						Wilson et al., 2004
Stress	5.0 – 10.0	1													Ray and Benefield, 1997
Harm	0.0 -5.0	1													Loosanoff, 1953
Mortality	0.0 – 5.0	7													Volety et al., 2003
<b>Adults</b>			X	X	X	X	X	X	X	X	X	X	X	X	
Stress	7.5 - 10.0														Woodward-Clyde, 1998
Harm	5.0 – 7.5	1													Loosanoff, 1953, 1965
Mortality	2.0 – 5.0	28													Loosanoff, 1953; Volety et al, 2003
Mortality	0.0 – 2.0	14													Roesijadi, 2004

## POLYHALINE ZONE VEC: SEAGRASSES

### Justification

Biological productivity and diversity in many estuarine systems is dependent upon healthy seagrass populations. It is generally accepted that the presence of healthy seagrass beds results in a diverse, dense and productive faunal community (Gilmore, 1995; Lewis, 1984; Thayer et al., 1984; Virnstein et al., 1983). Seagrass beds provide food for bacteria and microscopic animals at the base of a complex food web, as well as, food for larger organisms such as green turtles and manatees. Seagrasses offer a refuge and nursery for numerous commercially and recreationally important species including shrimp, fishes and crabs and their prey (Zieman, 1982; Phillips, 1984; Thayer et al., 1984; Kenworthy et al., 1988; Zieman and Zieman, 1989; Sogard et al., 1989). The majority of landed commercial and recreational fish spend at least some portion of their life histories using seagrass beds. Seagrass beds enhance water quality (Fonseca et al., 1983; Fonseca and Fisher, 1986; Fonseca, 1989; Fonseca and Cahalan, 1992) by providing an ideal substrate for periphyton that assimilate dissolved nutrients while the leafy seagrass canopy baffles waves and currents thus inhibiting resuspension of fine particles and trapping sediments (Ward et al., 1984).



Three of the seagrass species currently present in the Loxahatchee Estuary have fairly well defined salinity tolerances: shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), and turtle grass (*Thalassia testudinum*). Salinity thresholds documented in literature or observed in unpublished studies are presented as Performance Measures for these three species. There is limited data available on salinity thresholds for Johnson's seagrass (*Halophila johnsonii*), a threatened species currently abundant in the Loxahatchee Estuary. Accordingly, the best available salinity data will be used to help assess potential impacts to this threatened species. For consistency with the oyster PM, documented salinity tolerances were used to infer levels of stress to the seagrass communities for comparison of restoration scenarios. The levels of stress used for the seagrass evaluation are: no stress, potential stress, harm, and mortality (see **Chapter 5** for discussion of evaluation methodology).

## Distribution

Several seagrass mapping efforts have been conducted in the Loxahatchee Estuary (**Table 4-4**). Mapping techniques have ranged from outlining seagrass signatures on mylar over photographs and matching (best fit) this linework to base maps to the more precise technique of simultaneously interpreting/rectifying the habitat polygons using an analytical stereoplotter. Because of inconsistencies in mapping methods, all seagrass mapping data do not exhibit the same positional accuracy; therefore, caution should be used in comparing exact positions and acreages. However, general comparisons of the various maps provide a good indication of where persistent seagrass beds exist and areas of greatest change over time. Available seagrass maps were reviewed along with associated reports and are summarized below.

**Table 4-4.** Summary of Seagrass Mapping Studies of the Loxahatchee Estuary.

Year	Map Area	Mapping Methods	Lead Agency	Apparent Seagrass Gains/Losses	Reference
1980-1981	Embayment to Inlet	Seagrass signatures outlined on photo overlay based on limited groundtruthing then "best fit" to base map.	USGS		McPherson et al., 1982
1985	River forks and Embayment to inlet and south end of Indian River Lagoon	Detailed groundtruthing, linework "best fit" to 1970 property appraisal composite photograph.	Palm Beach County Health Department	Gain	Klemm and Vare, 1985
1990	River forks and Embayment	Groundtruthing results mapped onto aerial photos using bearings to local landmarks.	Jupiter Inlet District (JID)	Loss	Law Environmental Inc., 1990
1994	River forks and Embayment	Groundtruthing with GPS to confirm signatures on aerial photo signatures.	JID	No change	Applied Technology and Management, Inc., 1994
1996	River forks and Embayment	Groundtruthing with GPS to confirm aerial photo signature; edges of grass beds were surveyed using GPS.	JID	Significant loss	Cutcher, 1999
1998	River forks and Embayment	Groundtruthing with GPS to confirm aerial photo signature; edges of grass beds were surveyed using GPS.	JID	Slight gain	Cutcher, 1999

Year	Map Area	Mapping Methods	Lead Agency	Apparent Seagrass Gains/Losses	Reference
2000	Embayment and entrances to 3 tributary forks	Groundtruthing with GPS to confirm aerial photo signature; edges of grass beds were surveyed using GPS.	JID	Gain	Cutcher, 2000
2003	Embayment and entrances to 3 tributary forks	Groundtruthing with GPS to confirm aerial photo signatures; analytical stereoplotted.	LRD/ SFWMD	Gain	Avineon, Inc., 2003
2003-2004	Upstream of the A1A bridge to RM 6.5	Species-specific map based on detailed groundtruthing with GPS.	LRD/ SFWMD	Gain in manatee grass since 1985	Loxahatchee River District, 2004

For this plan, the SFWMD had 1980-81, 1985, and 2003 seagrass data prepared in Geographic Information System (GIS) format for general comparison. Maps from these data are presented below. The other maps referenced in **Table 4-4** were reviewed along with associated reports but were not available in GIS format; consequently, they are summarized below but not presented in graphic format.

### **Early 1900s - 1969**

Prior to stabilization in 1947, the Jupiter Inlet periodically opened and closed. Anecdotal information indicates that seagrasses were present in the estuary at times when the inlet was open but specific locations and species composition are not known (Cary Publishing, Inc., 1973). After the inlet was stabilized in the 1940s and salinity and water clarity became favorable, it is likely that seagrasses were persistent in the estuary. Additional anecdotal information indicates that seagrass beds “thrived” from 1957-1969 along the west shore of the Northwest Fork approximately 0.5 mile upstream of Pennock Point (McPherson et al., 1982; see note on **Figure 4-8**). If seagrasses thrived in this reach of the Northwest Fork, it is likely that they also thrived downstream in the embayment during that time period.

### **1980 – 1985**

The first known seagrass map of the Loxahatchee Estuary was prepared in 1980/81 by the U.S. Geological Survey (USGS; McPherson et al., 1982). This map shows seagrass coverage within and downstream of the Embayment, but not within the river forks. It is unclear whether this survey included the forks or if the forks were inspected and no seagrasses were present.

Although the 1980/81 map does not depict species distribution, detailed text published with the map indicates that shoal grass was the dominant species and manatee and turtle grass were rare. The map text also indicates that *Halophila* was sometimes found growing with shoal grass, but the species of *Halophila* was not noted.

In 1985, the Palm Beach County Heath Department mapped Loxahatchee seagrasses by species (Klemm and Vare, 1985). They noted the same species observed in 1980/81. As with the 1980/81 mapping effort, shoal grass was the dominant species with manatee and turtle grasses being relatively rare in the embayment. The 1985 map showed seagrasses farther up the Northwest Fork than the anecdotal note mentioned above for the 1957-1963 time period.

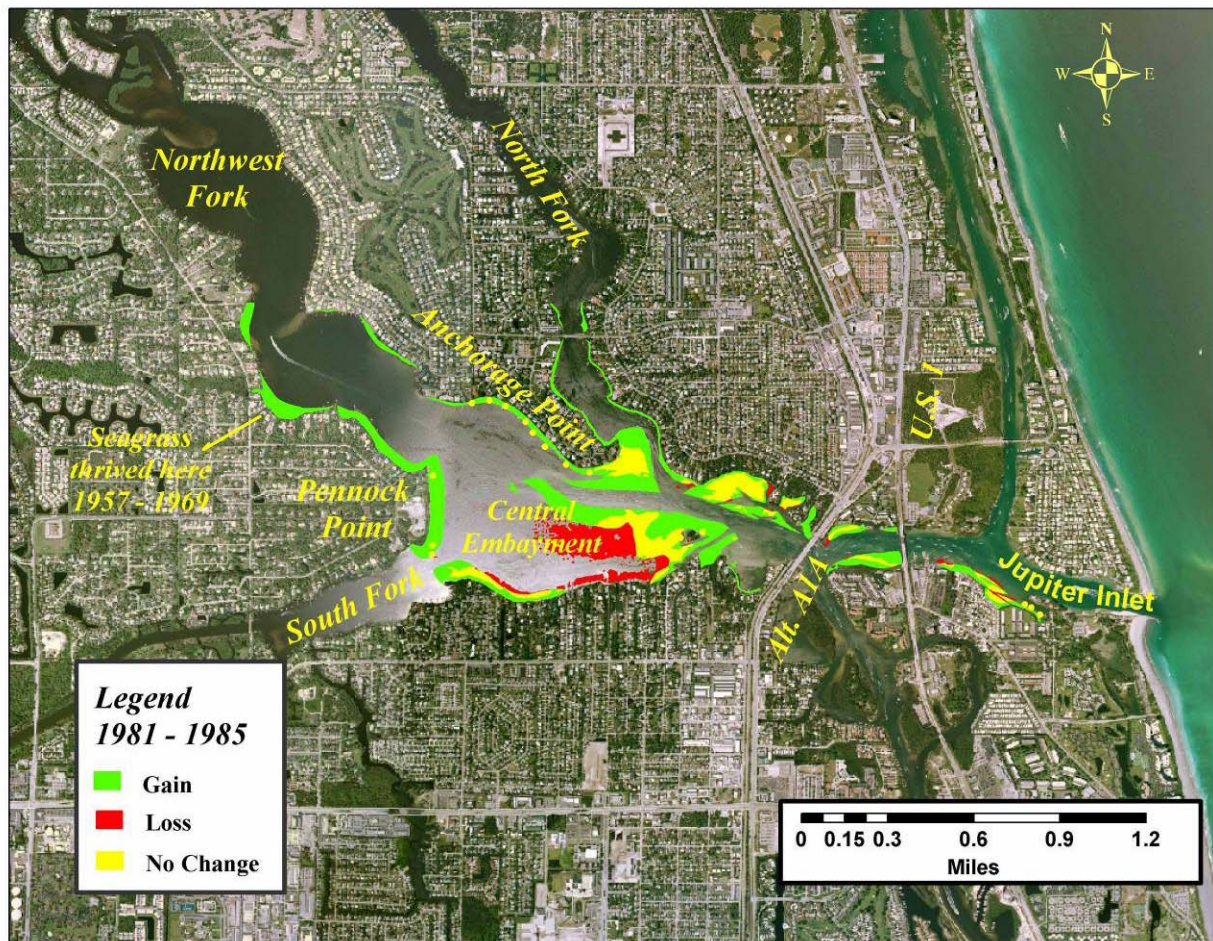
A general comparison of these early seagrass maps revealed some significant differences in seagrass distribution over the 4-year period (**Figure 4-8**). More than twice as much seagrass was mapped in 1985 than in 1980/81. Some of this apparent increase is due to seagrasses mapped in



the North and Northwest Forks in 1985 but not in 1980/81. As mentioned above, it is unclear whether the 1980/81 mapping effort included the forks so this apparent difference in seagrass coverage may or may not be real.

Other apparent increases in seagrass acreage occurred along Pennock Point and along the embayment shoreline up river of Anchorage Point. In 1980/81 only scattered patches of seagrass were present in these areas but by 1985 the patches appear to have coalesced into continuous beds. Seagrasses at the tip of Anchorage Point and in the sand bar area also appeared to expand significantly from the early to mid 1980s.

In contrast, the seagrass beds located immediately south of the sand bar and along the south shore of the embayment were lost. The area south of the sand bar is slightly deeper than surrounding areas. It is possible that seagrasses or macroalgae expanded to these depths during the drought of 1980-81 (because of reduced freshwater inflows which likely lead to better light penetration) then disappeared during the wetter years that followed. This would not, however, explain the loss of seagrasses along the shallow south shore of the embayment between 1980/81 and 1985.



**Figure 4-8.** Changes in Seagrass Distribution From 1980/81 to 1985. Sources: Klemm and Vare, 1985 and McPherson et al., 1982.

The 1980/81 map included bathymetric contours. A visual comparison of the bathymetric contours with the deep edge of the seagrass beds revealed that Loxahatchee Estuary seagrass beds were quite shallow in the early 1980s. Seagrasses rarely extended deeper than the 4-foot (mean sea level) contour line. Klemm and Vare (1985) noted that seagrass growth was also restricted to only the shallower areas of the estuary. They indicated that freshwater discharges from the Northwest and South Forks were observed to be “turbid and stained with tannin resulting in significantly reduced light penetration restricting the growth of submerged grasses to only the shallower areas.” They noted visibility of 20 – 30 feet near the inlet but only 3 – 4 inches in the western reaches of the embayment and in the forks. They found the densest seagrass beds closest to the inlet with the best water clarity and tidal flushing and the sparsest beds in areas of poor water quality and decreased light penetration.

### **1985 – 1990**

The Jupiter Inlet District (JID) began mapping seagrasses in 1990. To date, they have mapped Loxahatchee Estuary seagrasses in 1990, 1994, 1996, 1998, and 2000.

In 1990, four species of seagrass were found: shoal grass, manatee grass, turtle grass, and *Halophila sp.* (Law Environmental Inc., 1990). As with previous mapping efforts, shoal grass was the dominant species in the embayment, all seagrasses occurred in shallow areas, and the densest seagrass beds occurred near the inlet. Moving upstream from the railroad bridge, *Halophila* ended first and then turtle and manatee grass. Trace amounts of manatee grass were found along the west bank of the Northwest Fork.

Significant changes in seagrass distribution and acreage occurred from 1985 to 1990 (Law Environmental Inc., 1990). Seagrass losses exceeded gains. Losses were attributed to reduction in acreage within the North and Northwest Forks (beds receded downstream) and embayment (beds became dissected into isolated patches). The only important gain noted was in the vicinity of the railroad bridge; an area strongly influenced by oceanic water entering through the inlet. Species composition changes were also noted. The deep edge *Halophila* fringes observed in 1985 were no longer present in 1990. Manatee grass apparently moved up river to Anchorage Point and expanded into former shoal grass areas.

### **1990 – 1994**

Seagrass coverage in most areas of the estuary did not change much between 1990 and 1994. However, there was a distribution change in the sand bar area. The sand bar seagrass bed observed in 1990 was still present in 1994, however it apparently shifted slightly to the south and west. Accretion on the sand bar may be partly responsible for the shift (Applied Technology and Management, Inc., 1994). Four seagrass species were observed: shoal grass, manatee grass, turtle grass, and Johnson’s seagrass. The 1994 map was the first report we reviewed to document the presence of Johnson’s seagrass in the Loxahatchee Estuary. This threatened species was observed throughout the embayment in 1994 (Applied Technology and Management, Inc., 1994).

### **1994-1998**

A large loss of seagrass occurred from 1994 to 1996 (51%) with an apparent slight recovery (10%) from 1996 to 1998 (Cutcher, 1999). It is possible that increased freshwater discharges and reduced water clarity associated with high rainfall in 1994/95 may have contributed to the apparent seagrass decline. The increases in acreage observed from 1996 to 1998 were largely in the eastern section of the embayment. Shoal grass continued to be the dominant species from

1994 to 1998. Cutcher (1999) was the first report that specifically mentioned the presence of paddle grass (*Halophila decipiens*). Both paddle grass and Johnson's seagrass were considerably less abundant than shoal grass.

### **1998 - 2000**

Cutcher (2000) reported a 22% increase in seagrass coverage between 1998 and 2000. The increase in seagrass coverage occurred in both the eastern and western portions of the embayment. Shoal grass continued to be the dominant seagrass species. Cutcher (2000) suggested that the general drought conditions in the spring and summer of 2000 may have contributed to overall improvement in water quality and subsequent increase in seagrass coverage.

### **1998 – 2002 (Lower Embayment)**

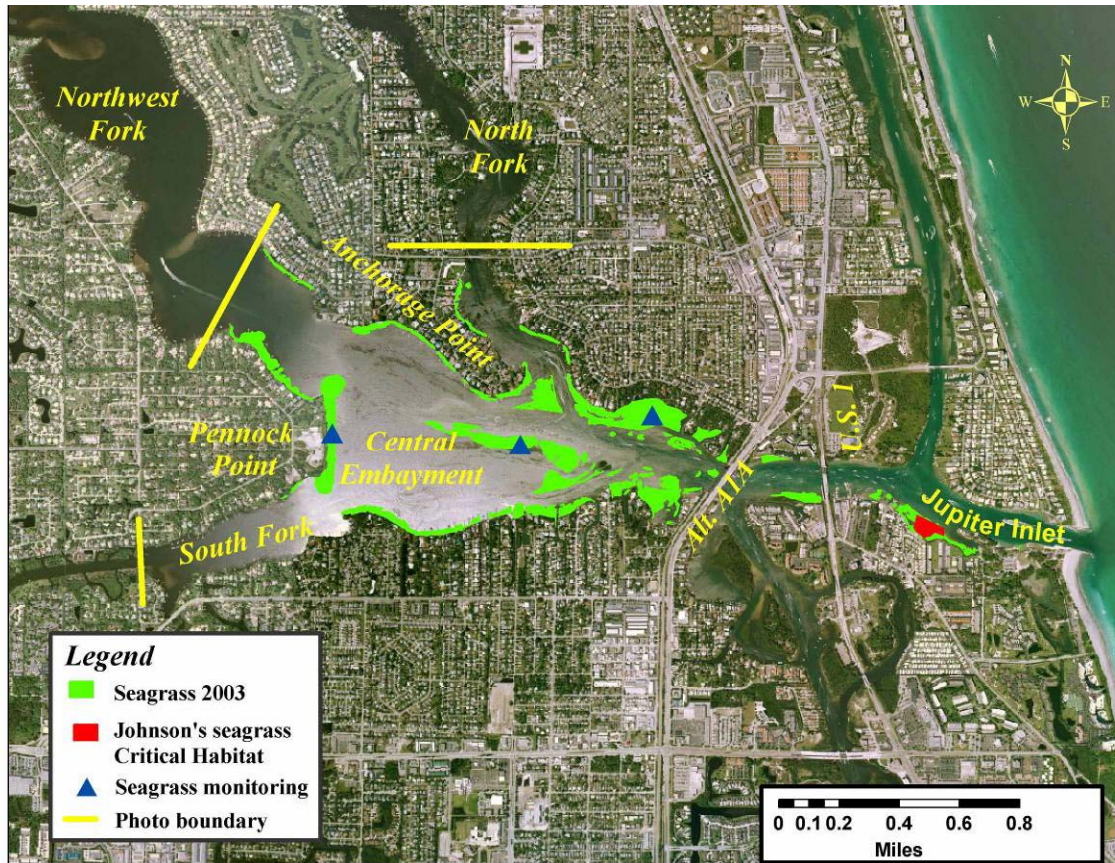
The Loxahatchee River District (LRD) conducted detailed mapping and monitoring in the south end of the Indian River Lagoon in 1998, 2000, and 2002 (Riddler et al., 1999, 2000, 2003). These studies included the most downstream portion of the Loxahatchee Estuary from the inlet to one and a half miles west of the inlet. Based on the LRD reports, seagrasses in this area continue to increase in density and composition. The density of Johnson's seagrass substantially increased over time. The LRD concluded environmental conditions in the section of the Loxahatchee Estuary closest to the inlet were favorable for multiple seagrass species to exist.

### **2003/2004**

In 2003, the South Florida Water Management District issued a contract to map Loxahatchee Estuary seagrasses using the same mapping method used for mapping the adjacent Indian River and Lake Worth Lagoons (**Figure 4-9**). This method entails using true color aerial photography, groundtruthing with GPS, and mapping using an analytical stereoplotter. The goal of the 2003 mapping effort was to map embayment seagrasses and the lower portions of the river forks (photo boundaries are shown on **Figure 4-9**).

A visual comparison of the 2000 and 2003 maps revealed a slight increase in seagrass coverage throughout the estuary. A comparison of the 2003 seagrass coverage with current bathymetric data was consistent with conclusion from the earlier mapping efforts; the average deep edge of the seagrass beds is shallow (approximately 3 feet mean sea level).





**Figure 4-9.** Seagrass Map Prepared From 2003 Aerial Photographs (Source: Avineon, Inc. 2003).

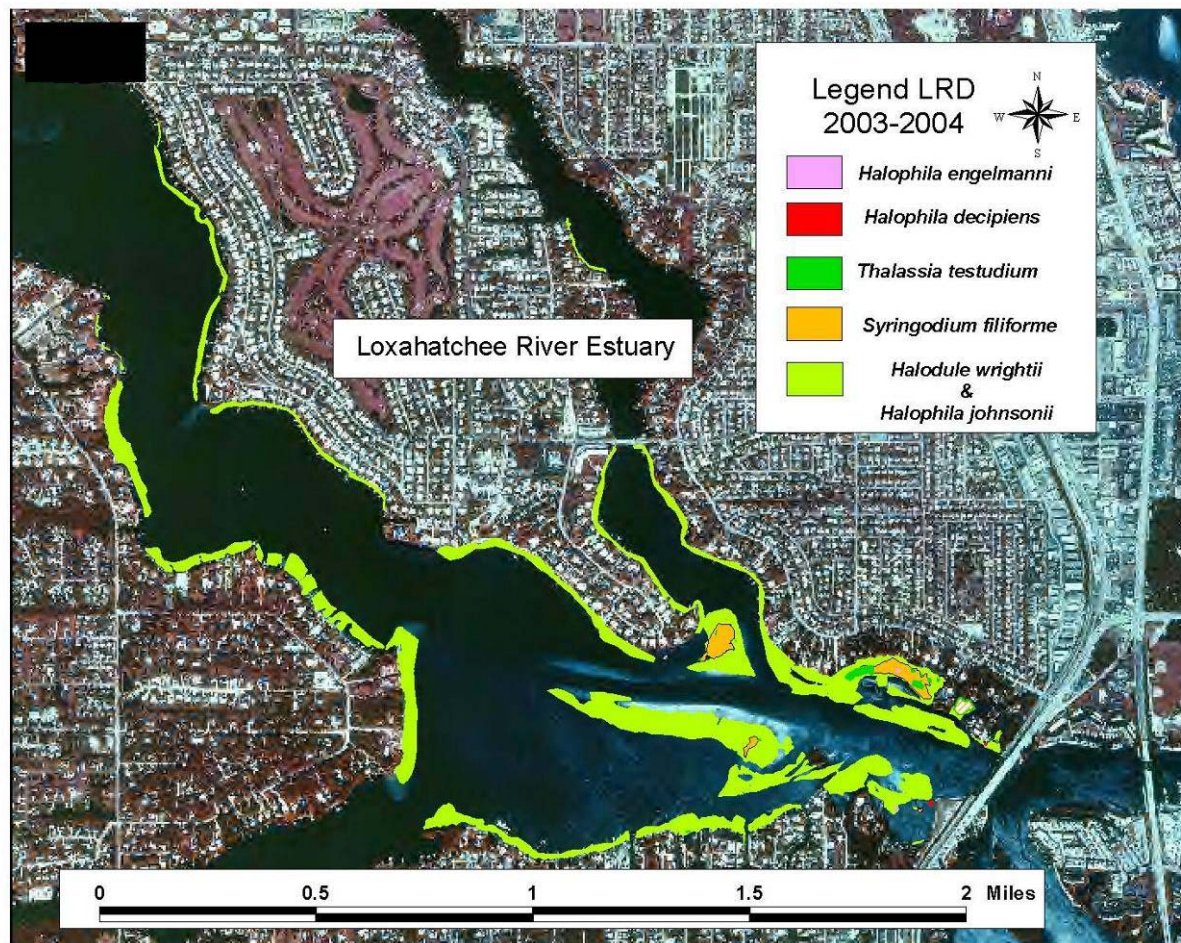
To supplement the 2003 mapping from aerial photography, the SFWMD partnered with the Loxahatchee River District to prepare a species-specific seagrass map (**Figure 4-10**; Loxahatchee River District, 2004). The species-specific map was prepared in 2003/2004 using detailed groundtruthing with a sub-meter accuracy, differentially corrected, GPS unit to document seagrass bed locations.

The groundtruthing effort for the species specific mapping effort revealed that seagrass beds existed upstream of the photography boundaries used for the 2003 mapping effort. Seagrass beds were found up river to approximately RM 3.4 and occasional patches of seagrasses were found near RM 4.0. The seagrass species found within the Northwest Fork included shoal grass and Johnson's seagrass.

Through the Loxahatchee River District's mapping effort, all seven species of seagrasses found in South Florida were documented in the Loxahatchee Estuary: shoal grass, manatee grass, turtle grass, paddle grass, Johnson's seagrass, star grass, and widegeon grass. The LRD's survey is the first known to document the presence of star grass and widegeon grass in the Loxahatchee Estuary. This survey agreed with previous studies which indicated that shoal grass is the dominant seagrass species in the Loxahatchee Estuary. Detailed maps prepared for each species can be found in the map report prepared by the Loxahatchee River District (Loxahatchee River District, 2004).



The only other known species-specific seagrass map of the Loxahatchee Estuary is the 1985 map (Klemm and Vare, 1985). A comparison of the 1985 and 2003/2004 maps revealed that shoal grass was the dominant species and occurred throughout the estuary on both maps. Turtle grass was present in the same location on both maps; the cove on the north side of the estuary approximately 0.3 miles upstream of Alternate A1A (North Bay site). *Halophila* was documented throughout the estuary in both efforts, but species of *Halophila* were only differentiated in the 2003/2004 map. The biggest difference in species distribution was the presence of manatee grass farther upstream in 2003/2004. In 1985, the upstream limit was the North Bay site. In 2003/2004 manatee grass occurred upstream to Anchorage Point and was found in the middle of the embayment across from Anchorage Point.



**Figure 4-10.** 2003/2004 Map of Seagrass Species in the Loxahatchee Estuary. Widgeon grass was found near River Mile 6.5 and is not shown on this map. (Source: Loxahatchee River District, 2004)

### **Seagrass Monitoring**

The South Florida Water Management District and the Loxahatchee River District partnered in the summer of 2003 to conduct detailed monitoring of seagrasses within the embayment of the Loxahatchee River. The monitoring sites are shown on **Figure 4-9**. The

purpose of this study is to document seasonal changes in seagrass and associated macroalgae (epiphytes, attached algae, and drift algae) over a 3-year period. Data collected will be used to better understand: (1) the natural seasonal variability of seagrass and macroalgae in the study area; and (2) the response of the seagrass community to freshwater discharges. Water quality data will also be collected to evaluate potential links between water quality (particularly salinity, light, and chlorophyll) and trends in seagrass and algae. Preliminary results of the first year of monitoring are under review.

### **Summary/Discussion**

It is likely that seagrass beds have been persistent features in the Loxahatchee Estuary since the late 1940s when the Jupiter Inlet was stabilized. Seagrass beds have been mapped numerous times from the late 1980s to present. Expansions and contractions of the beds have occurred over time but the core seagrass beds have persisted. Seagrass beds in the Loxahatchee Estuary tend to be most dense and diverse near the inlet and become less diverse and less dense at upstream locations. The upstream limit of seagrass “beds” appears to be near RM 3.0, with occasional patches of shoal and Johnson’s seagrasses upstream to near RM 4.0.

Shoal grass has been the dominant seagrass species in the estuary since at least the early 1980s. All species of seagrasses typically grow only in very shallow waters of the Loxahatchee Estuary. It is likely that the dark waters flowing from the river forks reduce light penetration through the water and limit the deep edge of the seagrass beds.

Dent (2000) states that salinity in the Loxahatchee “experiences significant shifts” due to freshwater inflow from the watershed, discharges through control structures, and tidal influence of ocean waters entering the estuary through the Jupiter Inlet. These dynamic salinity conditions may help explain the dominance of shoal grass in the estuary since this species tends to exhibit a broader salinity tolerance and ability to tolerate broad salinity fluctuations better than manatee grass, turtle grass, and the *Halophila* species (McMillan, 1974). These salinity fluctuations are less extreme at sites closest to the inlet where seagrass species diversity and density is the greatest.

Due to the dynamic nature of the Loxahatchee Estuary, we can expect seagrass distributions to continue to expand and contract with changes in salinity. Continued periodic mapping of the seagrass beds using accurate and consistent methodology, in conjunction with the site specific monitoring being conducted by the LRD will provide data which will help evaluate natural variability and assess impacts to seagrasses from freshwater discharges.

Seagrasses are an important and persistent feature of the Loxahatchee River. However, the seagrasses in the embayment already “exist near the edge of their tolerance” (Cutcher, 1999). Consequently, it is important that careful consideration be given to any potential impacts that upstream restoration efforts may have on the seagrass resources in the Loxahatchee Estuary

### **Performance Measures**

Salinity tolerances used in this plan were obtained from the literature or unpublished studies. The documented salinity tolerances were then grouped into three performance measure categories: 1) no stress, 2) potential stress, and 3) stress. Salinities within the “no stress” category are expected to provide optimal conditions for the seagrasses; no adverse impacts are expected to occur when salinities occur within this category. Salinities at which impacts to seagrasses have

been documented in either laboratory or field studies fall within the “stress” category. All other salinities were placed in a “potential stress” category for the performance measure evaluation. **Table 4-5** summarizes the salinity tolerances and identifies the salinity ranges within each stress category for each key seagrass species.

**Table 4-5.** Salinity Performance Measures for Fours Species of Seagrasses<sup>a</sup>.

Seagrass Species	Level of Salinity Stress	Salinity Threshold (ppt)*	Justification for stress level	Reference
Shoal grass ( <i>Halodule wrightii</i> )	No Stress	≥ 24	A literature review indicated that ≥ 24 ppt provided optimal conditions for shoal grass.	Woodward Clyde International Americas, 1998
	Potential Stress	13 - 23	This represents the range between optimal conditions and documented stress.	
	Stress	< 12	Very little growth occurred between 6 and 12 ppt in a laboratory experiment; blade mortality occurred below 6 ppt.	Doering et al., 2002; McMahan, 1968
Manatee grass ( <i>Syringodium filiforme</i> )	No Stress	≥ 23	A literature review indicated that ≥ 23 ppt provided optimal conditions for manatee grass.	Woodward Clyde International Americas, 1998
	Potential Stress	16 to 23	This represents the range between optimal conditions and documented stress.	
	Stress	≤ 15	Two separate laboratory studies showed impacts at this threshold (in one experiment blade densities declined rapidly in another study leaf extension rates declined rapidly).	Unpublished SFWMD, 1999; Lirman and Cropper, 2003
Turtle grass ( <i>Thalassia testudinum</i> )	No Stress	≥ 25	This value is based on optimal conditions stated in a literature review.	Woodward Clyde International Americas, 1998
	Potential Stress	20-24	This represents the range between optimal conditions and documented stress.	
	Stress	≤ 19	In one study, limited growth was observed between 16-19 ppt and in another study photosynthesis decreased by one third at 18 ppt. Growth parameters were negatively impacted in a laboratory experiment at salinities between 6 and 12 ppt.	Woodward Clyde International Americas, 1998; Doering and Chamberlain, 2000
Johnson's seagrass ( <i>Halophila johnsonii</i> )	No Stress	≥ 25	This value is based on optimal conditions stated in a literature review.	Woodward Clyde International Americas, 1998
	Potential Stress	15-24	The documented range stated in the Final Recovery Plan for this threatened species is 15–43 ppt so this evaluation assumes that below optimal conditions and within the documented range there is potential for stress.	National Marine Fisheries Service, 2002
	Stress	≤ 14	The documented range stated in the Final Recovery Plan for this threatened species is 15–43 ppt so this evaluation assumes that salinities below 15 ppt would be stressful for this threatened species.	National Marine Fisheries Service, 2002

<sup>a</sup> Since this project is evaluating impacts from reductions in salinities, only the lower limit of the “no stress” zone is included in this table

In a few cases, the available literature and unpublished studies documented a duration associated with a salinity threshold that resulted in severe stress such as blade mortality. **Table 4-6** summarizes this information for each of the four key species. This salinity/duration data provides an additional performance measure for each species.



**Table 4-6.** Salinity/Duration Performance Measures for Four Species of Seagrasses.

Seagrass Species	Salinity Threshold (ppt)*	Justification for “severe stress”	Reference
Shoal grass ( <i>Halodule wrightii</i> )	< 6 ppt for 30 days; 3.5 ppt for 21 days	Blade mortality occurred at these salinities in laboratory experiments.	Doering et al., 2002; McMahan, 1968
Manatee grass ( <i>Syringodium filiforme</i> )	< 15 ppt for 26 days	In a lab experiment, blade densities declined rapidly after 26 days. Additionally, field observations revealed that after six weeks of salinities < 15 ppt blade mortality occurred.	Unpublished SFWMD, 1999; Dan Haunert, personal observation.
Turtle grass ( <i>Thalassia testudinum</i> )	≤ 4 ppt for 7 days	Based on one laboratory experiment no green material was left after a few days at 5 ppt, however, a more recent study showed survival at 5 ppt after 2 weeks (although leaf elongation was reduced). A literature review indicated a short-term (up to about 7 days) limit of 4 ppt; this limit is used for this evaluation.	McMillan, 1974; Lirman and Cropper, 2003; Woodward Clyde International Americas, 1998
Johnson's seagrass ( <i>Halophila johnsonii</i> )	5 ppt for 3 days	Blade mortality occurred at this salinity in a laboratory study.	Dawes et al., 1989

Although none of the available studies used to develop the above stress categories were conducted in the Loxahatchee Estuary, data from these studies provide the best available information for this preliminary evaluation. These performance measures will allow a consistent comparison of model runs to assess potential impacts of proposed upstream restoration efforts on the seagrass resources.

The following chapters will discuss the watershed hydrology and estuarine salinity models developed as management tools for the Restoration Plan for the Northwest Fork of the Loxahatchee River. These models predict daily freshwater input and daily mean salinity at selected locations in the Loxahatchee River. Therefore, time series of inflows representing existing watershed hydrology (base case) as well as modeled alternative hydrology scenarios can be used to predict long term salinities throughout the estuary. The results from these modeled flow and salinity data are then compared with the VEC salinity Performance Measures to evaluate and contrast the effect on the VECs, therefore providing a measure of success for different hydrological scenarios.

## **CHAPTER 5**

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## **Chapter 5:**

# **Determining Hydroperiods and Flow Requirements in the Riverine Floodplain**

There are four critical hydrological factors that heavily influence the integrity of the vegetative community types that exist in the riverine floodplain of the Northwest Fork of the Loxahatchee River. These are the maximum dry season water elevations in the river channel, the minimum wet season water elevations in the floodplain, the durations of each, and the water stages over the floodplain during the transitional periods. An effective restoration strategy must provide a mechanism and a management plan for each of these factors.

There is a direct relationship between river stage/floodplain inundation and volume of water being delivered to the system from upstream areas. Management of flows from those upstream areas is the primary mechanism by which the critical hydrological factors can be manipulated to achieve restoration goals.

A guiding principle of the restoration plan is that no element of the watershed will be enhanced at the expense of another. The riverine floodplain between Riverbend Park and Trapper Nelson's is generally considered to be a good quality functional ecosystem typical of riverine floodplains. Any adjustments in hydrology must cause no harm and where possible enhance the ecological function of the system. Applying a commonly used regulatory tool for evaluating the current state of the wetland system function, it is possible to compute a quantitative score that documents the current functional ecological health of the riverine floodplain. This score will serve as a benchmark against which the health of the system can be evaluated and compared at any future date. It is anticipated that hydrological regimes developed for the Northwest Fork of the Loxahatchee River as part of the restoration plan will not cause a degradation in score and may, in fact, enhance it. The scoring process and development of the recommended hydrological regimes for the wet and dry seasons are discussed in this chapter.

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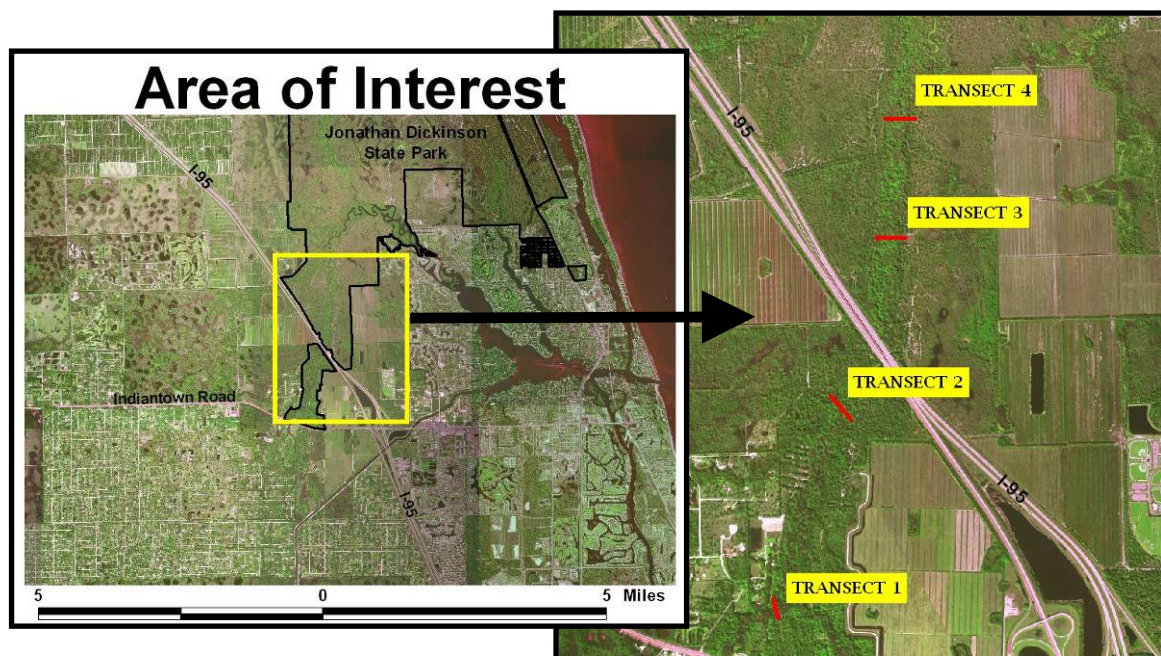
### **HABITAT QUALITY EVALUATION**

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The riverine floodplain from the Riverbend Park (RM 15.4) to Trapper Nelson's (RM 10.5) is mostly populated by a desirable mix of canopy and understory vegetative species. The quality of the floodplain community was documented on August 19, 2004 by a team of wetland scientists, biologists and engineers as a part of the ecological benefit/impact analyses of the North Palm Beach County-Part I project. Wetland Rapid Assessment Procedures (WRAP; Miller and Gunsalus, 1997) were utilized in the functional assessment of the proposed ecosystems. WRAP is an established methodology for assessing a wetland/ecological community that takes into account the overall quality of the ecosystem being evaluated through a process of rating a number of predefined variables. WRAP has been statistically validated with respect to repeatability and the measurement of independent variables. It is currently used by the United States Army Corps of Engineers (USACE) in the State of Florida as part of the 404 Regulatory Permitting process. It was also used locally in the "Loxahatchee River Basin Wetland Planning Projects for Martin and Palm Beach Counties" (Treasure Coast Regional Planning Council 1999; Martin County Growth

Management Department, 2000). The final WRAP score, for a given area, is a numerical value between 0 and 1, with 0 representing no functional value and 1 representing a system functioning at a very high level.

The habitat quality of the Northwest Fork riverine floodplain communities was assessed using WRAP for four transects established perpendicular to the river channel across the floodplain (**Figure 5-1**). These transects are located in the upstream portions of the riverine reach of the Northwest Fork and are not influenced by saltwater intrusion from intertidal mixing as are transects located further downstream. The assessment team's field observations of the different community types as well as the assigned WRAP score and justifications are described in the following discussion. More descriptive information can be found in "Procedural Approach for Ecological Benefit and Impact Analyses of Alternative Plans: North Palm Beach County Part I Watershed Wetlands" (Draft Final Report, in prep).



**Figure 5-1.** Riverine Reach of Northwest Fork of Loxahatchee River.

Evaluation Polygon #1 (NWF-1) represents the communities located upstream from Masten Dam and contains Transect 1 and Transect 2-1 (**Tables 5-1 and 5-2**). Transect 1 is located just downstream of Lainhart Dam (RM 14.5) whereas Transect 2-1 is located upstream of the western side of Masten Dam (RM 13.57). The vegetative communities within this polygon are intact, and are dominated by hydric hammocks and floodplain swamps. The floodplain forest canopy is well established and provides good habitat support to wildlife. Duration and frequency of inundation in the floodplain is shortened due to the reduced freshwater inflows to the River and regional lowering of water tables. This polygon received a WRAP score of 0.81.

**Table 5-1.** Wetlands Evaluation Summary of the Riverine Reach of the Northwest Fork of Loxahatchee River Upstream of Masten Dam at Transect 1 Using the Wetland Rapid Assessment Procedure (WRAP).

<b>Natural Area:</b>	Northwest Fork of the Loxahatchee River
<b>Site:</b>	Transect 1
<b>Polygon Number:</b>	NWF-1
<b>Date of Visit:</b>	08/19/04
<b>Assessment Team Members Present:</b>	B. Gunsalus (SFWMD); D. Roberts (FPS); J. Fisher (FPS); E. Cowan (FPS); P. Balci (E&E)
<b>Dominant FNAI Community Type(s):</b>	Floodplain Swamp; Hydric Hammock
<b>Wildlife Utilization:</b>	Score = 2.5; impacts on hydrological deliveries; also slight impacts to the adjacent buffers providing habitat support for wildlife.
<b>Wetland Overstory/Shrub Canopy:</b>	Score = 3.0; dominated by desirable and appropriate plant species.
<b>Vegetative Ground Cover:</b>	Score = 2.5; mostly desirable species but exotic elephant ear ( <i>Xanthosoma sagittifolium</i> ) also present.
<b>Adjacent Upland/Wetland Buffer:</b>	Avg. Score = 2.56 External buffer score = 2.5 (Major roadway [Indian Town Road] 25%; Natural areas-75%) Internal buffer score = 2.62 (Jupiter Farms-25%; Natural areas-75%)
<b>Field Indicators Of Wetland Hydrology:</b>	Score = 2.0; Hydroperiod duration is shorter and water delivery is controlled.
<b>Water Quality Inputs And Treatment:</b>	Score = 2.5; close to Jupiter Farms (~25%impacts)
<b>Overall WRAP Score:</b>	0.81
<b>Other comments</b>	Ground level elevation data are available for Transects 1 and 2-1.

**Table 5-2.** Wetland Evaluation Summary of the Riverine Reach of the Northwest Fork of the Loxahatchee River Upstream of Masten Dam at Transect 2-1 Using the Wetland Rapid Assessment Procedure (WRAP).

<b>Natural Area:</b>	Northwest Fork of the Loxahatchee River
<b>Site:</b>	Transect 2-1; Canal 3
<b>Polygon Number:</b>	NWF-1
<b>Date of Visit:</b>	08/19/04
<b>Assessment Team Members Present:</b>	B. Gunsalus (SFWMD); D. Roberts (FPS); J. Fisher (FPS); E. Cowan (FPS); P. Balci (E&E)
<b>Dominant FNAI Community Type(s):</b>	Floodplain Swamp; Hydric Hammock
<b>Wildlife Utilization:</b>	Score = 2.5; hydrological deliveries are shortened; also slight impacts to the adjacent buffers providing habitat support for wildlife.
<b>Wetland Overstory/Shrub Canopy:</b>	Score = 3.0; Hydric hammock is dominated by cabbage palm whereas pop ash and bald cypress are the dominant species in the floodplain swamp.
<b>Vegetative Ground Cover:</b>	Score = 2.0; some exotics <10% (i.e. <i>Syngonium podophyllum</i> ) but dominated by native species (i.e. <i>Thelypteris interrupta</i> ; <i>T. dentata</i> , <i>Acrostichum danaeifolium</i> )
<b>Adjacent Upland/Wetland Buffer:</b>	Avg. Score = 2.3 External buffer score = 1.8 (Old agricultural site-75%; Major roadway-Indian Town Road-25%) Internal buffer score = 2.8 (Indian Town Road-10%; Natural areas-90%)
<b>Field Indicators Of Wetland Hydrology:</b>	Score = 2.0; Hydroperiod duration is shorter and water delivery is controlled



<b>Water Quality Inputs And Treatment:</b>	Score = 2.7 (LU=2.6; PT=2.8)
<b>Overall WRAP Score:</b>	0.81
<b>Other comments</b>	Elevation data are available for Transect 2-1.

The second evaluation polygon (NWF-2) represents the communities located downstream from Masten Dam and includes Transect 2-2, Transect 3 and Transect 4 (**Table 5-3**). Transect 2-2 is located downstream of Masten Dam on the west side of the Northwest Fork of the Loxahatchee River (RM 13.43); Transect 3 is located approximately 0.7 miles downstream of I-95 and the Florida Turnpike on the east side of the river (RM 12.07); Transect 4 is located on the west side of the river at RM 11.18 approximately 0.7 miles upstream of Trapper Nelson's Interpretive Site. Similar to the first polygon, hydric hammock and floodplain swamp are the dominant community types observed within this polygon. Canopy is impacted by the presence of Old World climbing fern (*Lygodium microphyllum*) especially at Transect 3. Hydrological impacts are similar to those observed in other floodplain transect and are caused by reduced freshwater inflows and regional lowering of water tables. The WRAP score for this polygon was 0.83.

**Table 5-3.** Wetland Evaluation Summary of the Riverine Reach of the Northwest Fork of the Loxahatchee River Downstream of Masten Dam for Transects 2-2, 3, and 4 Using the Wetland Rapid Assessment Procedure (WRAP).

<b>Natural Area:</b>	Northwest Fork of the Loxahatchee River
<b>Site:</b>	Transect 2-2, Transect 3 and Transect 4
<b>Polygon Number:</b>	NWF-2
<b>Date of Visit:</b>	08/19/04
<b>Assessment Team Members Present:</b>	B. Gunsalus (SFWMD); D. Roberts (FPS); J. Fisher (FPS); P. Balci (E&E)
<b>Dominant FNAI Community Type(s):</b>	Floodplain Swamp; Hydric Hammock
<b>Wildlife Utilization:</b>	Score = 2.5; habitat support (buffer) and water deliveries slightly impacted
<b>Wetland Overstory/ Shrub Canopy:</b>	Score = 3.0; Hydric hammock is dominated by cabbage palm whereas pop ash and bald cypress are the dominant spp. in the floodplain swamp.
<b>Vegetative Ground Cover:</b>	Score = 2.5; some feral hog impacts on ground cover within the hydric hammock
<b>Adjacent Upland/ Wetland Buffer:</b>	Avg. Score = 2.2 External buffer score = 1.8 (Old agricultural site-50%; Major roadway (I-95)-33%; Natural areas-17%) Internal buffer score = 2.5 (Natural areas-100%)
<b>Field Indicators of Wetland Hydrology:</b>	Score = 2.0; Hydroperiod duration is shorter; delivery of water controlled for anthropogenic activities.
<b>Water Quality Inputs And Treatment:</b>	Score = 2.7 (LU=2.6; PT=2.8)
<b>Overall WRAP Score:</b>	0.83
<b>Other comments</b>	Elevation data are available for Transect s 2-1, 3 and 4.

The existing canopy and understory vegetative species composition is documented in the Transect Vegetation Summaries provided in **Chapter 3** of this document.

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## FLOODPLAIN HYDROLOGY EVALUATION

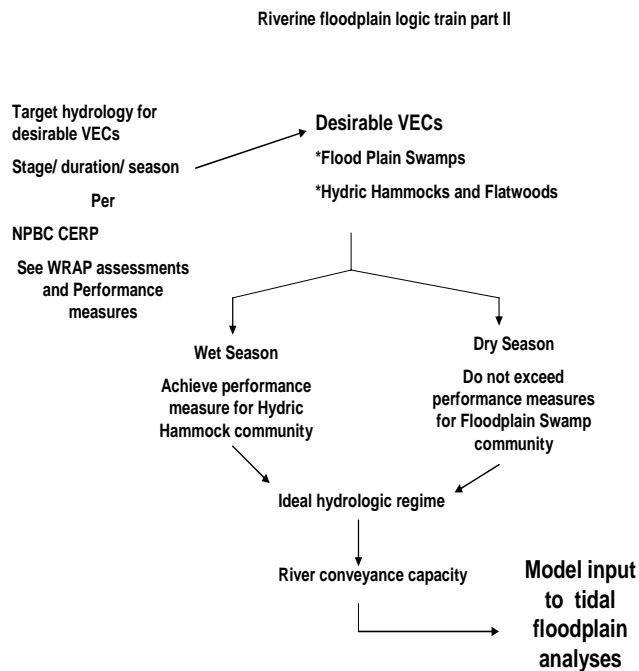
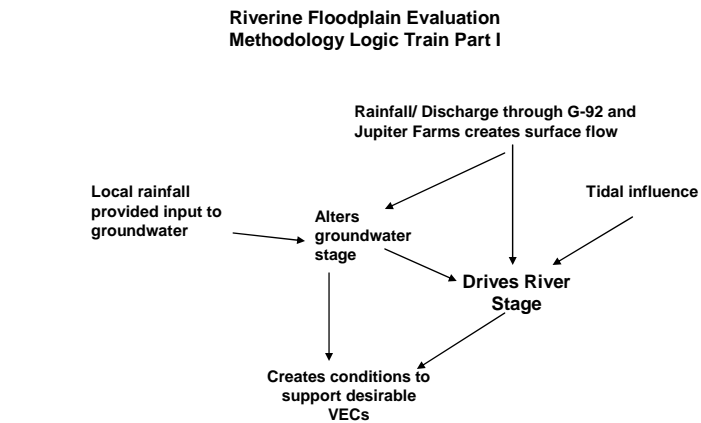
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Development of the evaluation methodology for riverine floodplain hydrology began with a list of assumptions that were put forth and universally agreed to as the fundamental common basis on which to build an evaluation strategy. The fundamental driving assumption around which the rest of the restoration effort is based is that the portion of the Northwest Fork of the Loxahatchee River from Riverbend Park to Trapper Nelson's has a healthy vegetative community typical of a riverine floodplain system (confirmed during WRAP evaluation) and that any restoration option considered for the lower reaches of the Northwest Fork and the rest of the Loxahatchee River or estuary will in no way adversely impact, harm, or compromise the biological health and integrity of that system.

Other assumptions are as follows:

- For this analysis, riverine reach of the Northwest Fork floodplain extends from Riverbend Park (RM 15.4) to Trapper Nelson's (RM 10.5).
- There are no salinity issues that need to be addressed in this portion of the watershed. However, at sites below Masten Dam tides may cause fluctuations in water depth.
- The current stage/discharge rating curve for Lainhart Dam is accurate and seepage around the structure is negligible (see Gonzalez, June 2004, Rating Improvements for Lainhart Dam, SCADA & Hydro Data Management, Technical Publication SHDM #1). This assumption needs to be reaffirmed following the major 2004 storm events.
- Existing (pre-Hurricane Frances) canopy vegetation represents desirable climax species; hydrological conditions need to continue supporting the necessary recruitment and growth of these canopy species.
- Existing shrub and groundcover vegetation may not be appropriate and suitable adjustments in floodplain hydroperiod could be considered and implemented to create conditions favorable to maintain a more "typical" lower tier vegetative community.
- Desirable vegetative communities are the "Floodplain Swamps" and "Hydric Hammocks" as described by NPBC CERP VEC performance measure guidelines. See **Chapter 3** of this document for plant community descriptions.
- Achieving hydrological performance measures for "Hydric Hammocks" will concurrently meet and achieve hydrologic performance measures for floodplain swamps during the wet season.
- Achieving hydrological performance measures for "Floodplain Swamps" will concurrently meet and achieve hydrologic performance measures for the entire floodplain community during the dry season.

The evaluation methodology strategy depicted in **Figure 5-2** is based on the foregoing assumptions. It depicts the drivers that result in given river stages and the hydrological constraints that, if exceeded, will result in adverse impacts to the existing system.



**Figure 5-2.** Riverine Floodplain Evaluation Methodology and Logic Train I and II.

Ultimately hydrological input sources and resulting river/floodplain surface water stages must be consistent with floodplain vegetative habitat type needs for stage, season, and duration.

Vegetative habitat hydrological performance indicators for the two critical habitat types were developed from literature and consensus of wetland professionals working through the NPBC CERP process. The seasonal hydrograph Performance Measures (PMs) are discussed in **Chapter 4**.

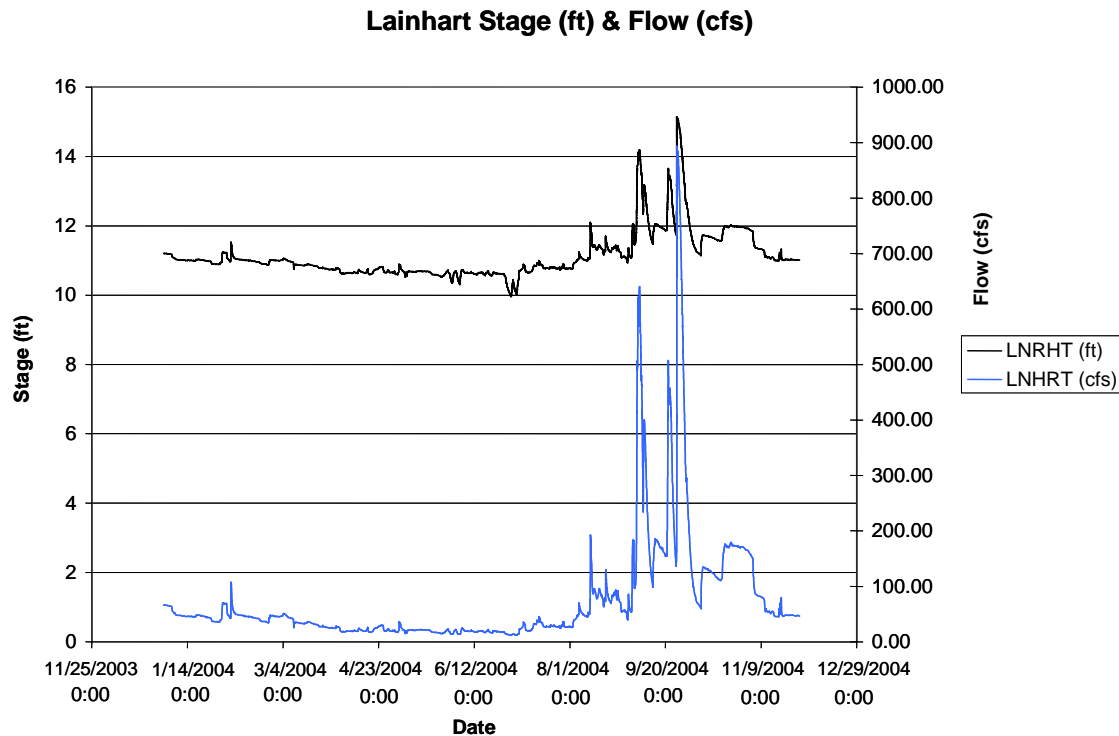
## FIELD ACTIVITIES

Hydrological flow/stage response in the riverine floodplain was determined through actual stage measurements in the river and floodplain under known flow conditions at Lainhart Dam. These measurements were taken at the vegetative Transects 1 through 4 which were established and surveyed in June and July 2003. At lower flow conditions (flow confined within channel banks) staff were able to make flow measurements at the transect location itself.

A controlled release study was performed on August 17, 2004 during which time water stage observations were made at each transect during a continuous 12-hour period. The goal was to develop the stage/flow relationship in the river downstream of Lainhart Dam and make direct observations of water stages in the river channel and floodplain that would lead to identifying the maximum channel flow capacity during the dry season that would not adversely affect the floodplain vegetative community. The 12-hour duration of the measurements at Transects 2 and 4 allowed the direct observation of tidal influence on stages and discharges at the most downstream portion of the protected riverine floodplain (Transect 4) and the most upstream portion of the riverine floodplain that would possibly be affected (Transect 2).

The controlled releases created a relatively constant flow at Lainhart Dam of 80-83 cfs. Simultaneously, real time flow measurements were obtained in the river channel at Transects 2 and 4. The measurements were made by technicians from the SFWMD SCADA & Hydro Data Management Department. They were accompanied by wetland experts and staff members from the SFWMD, FPS District 5 office, and other agencies. Gonzalez (2005) provides a full description of the study results and conclusions in SFWMD Technical Publication SHDM Report #2005-01. A copy of this document is included in **Appendix E**.

For the purposes of this evaluation it was necessary to have a high degree of confidence that the antecedent hydrological conditions were representative of typical dry season patterns. Discharge and river stage elevation measurements for the 8-month period prior to the controlled release study are depicted in **Figure 5-3**. The continuous nature of flows of less than 35 cfs and stages of 11 feet NGVD or less at Lainhart Dam throughout the 8-month period prior to the controlled release study on August 17, 2004 provides confidence that data collected during the study is indicative of normal dry season riverine floodplain responses to the range of discharge conditions during the study. An attempt was made to identify the degree that tidal activity influenced water stages in this portion of the river. Low tides at Boy Scout Dock (RM 5.9) on August 17 were at 5:45 am and 6:00 pm while high tides were at 11:12 am and 11:36 pm. Tidal range for the period was predicted to be between 0.1 to 2.4 feet NGVD.



**Figure 5-3.** Northwest Fork River Stages and Flows at Lainhart Dam for the Period November 2003 through December 2004.

The flows in the Northwest Fork of the Loxahatchee River measured by the Operations and Hydro Data Management staff on August 17, 2004, in support of the Loxahatchee River stage discharge development effort, were collected with a StreamPro acoustic profiler manufactured by RD Instruments (RDI), see **Figure 5-4**. StreamPro is a small monostatic, four-transducer, 2400-KHz Acoustic Doppler Current Profiler (ADCP) mounted on a tethered platform.

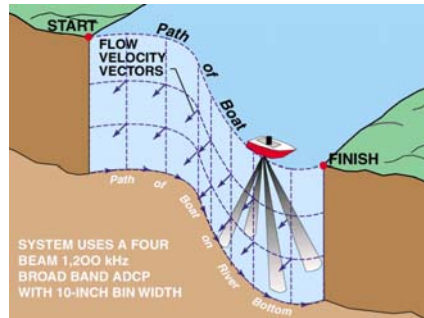


**Figure 5-4.** StreamPro 2400-KHz Acoustic Doppler Current Profiler (ADCP).

## Operating Principles

RDI's ADCPs measure the velocity of the water, track its path, and measure the channel depth as they move across the stream. ADCPs operate based on Doppler-shift principles using a proprietary broad-band acoustic signal processing algorithm for estimating the water velocity, flow depth, and bottom tracking. In an ADCP transect measurement the ADCP collects data at a frequency of about 1 Hz as it transects the river from one bank to the other, while operated via radio modem from a hand-held computer (**Figure 5-5**). The velocity, transect, and depth data are combined according to the velocity-area method, in a fashion similar to the traditional discharge

measurements by mechanical current meters described in the ISO Standard 748 (1997). ADCPs use “instantaneous” velocity profiles for computing discharge instead of using one, two, or three point-velocity measurements as traditionally done in mechanical current-meter measurements. ADCPs are not able to measure water velocities near solid boundaries, near the free surface, nor very close to the instrument because of acoustic signal contamination. To estimate the unmeasured discharge, the discharge computation algorithm makes use of extrapolation routines. The total discharge is computed as the summation of the measured discharge and estimated discharge.



**Figure 5-5.** Schematic of the operation of a broadband boat-mounted, four-transducer ADCP.

## Measurement Procedures

### **STEADY FLOWS**

Streamflow measurements with the StreamPro under steady flow conditions were made following the guidelines developed by the USGS (2002a, 2002b) for estimating open-channel flow discharge in steady flow conditions with boat-mounted ADCP measurements. These guidelines recommend estimating the streamflow discharge as the average of four reciprocal transects (transects made on alternate directions) within 5% of each other; if this condition is not met, discharge is estimated as the average of eight reciprocal transects.

### **TIME-VARYING FLOWS**

Streamflow measurements of varying flows, such as at tidally affected flows, are typically single transect estimates. Multiple samples can only be made by concurrently collecting transect data with several StreamPro profilers. Although our unit currently has two such meters, we were not able to collect multiple sample measurements because data was being collected at various river measuring stations. The USGS guidelines recommended for ADCP operation under steady flow conditions in terms of moving-bed checkings, transect measurement protocols were observed during these measurements.

## Results and Observations of the Controlled Release Study

Data analyses and results of the controlled release study are discussed in detail in **Appendix D**. In summary, tidal range at RM 5.9 (Boy Scout Dock) during the controlled release study on August 17 was approximately 2.4 feet. The amplitude of the stage at Transect 4 was about 0.7 feet while at Transect 3, the stage varied only by about 0.1 foot. The bankfull capacity at Transects 3 and 4 can be estimated by combining the discharge-at-Lainhart Dam against stage-at-transect curves with the direct stage-discharge data collected at the transects for an inland base flow of about 80 cfs and a tidal amplitude of 2.5 feet at Loxahatchee RM 9.1, and estimates of the bankfull stages. No observable tidal effects were found to influence river stages at Transects 1 and 2. Thus stage and discharge are uniquely related at Transect 1 and 2, and the bankfull capacity of these sites can be estimated from the discharge-at-Lainhart Dam against stage-at-

transect curves. Discharge at Lainhart Dam is the controlling factor of stage at Transects 1 and 2. Tidal influence and discharge at Lainhart Dam are cofactors in stage at Transects 3 and 4. The bankfull channel capacities derived from these data under the studied tidal conditions were 98, 144, 110, and 100 cfs respectively at Transects 1, 2, 3, and 4.

### Other Field Observations

Over the period from July 27 through December 1, 2004 FPS and SFWMD staff had the opportunity to observe and measure river surface stages at the transects on several occasions. In each case, recorded flow at Lainhart Dam was noted and in some cases rough measurements of submerged channel cross sections and flow velocities provided a rough estimate of actual flow volumes at the transect location itself. These were compared to the actual flow volume recorded at Lainhart Dam for the same period to confirm accuracy. Observations of extent and depth of floodplain inundation were noted at the same time that these river stage observations and discharge measurements were made. **Table 5-4** lists the dates and transect locations where visual observations and measurements of water surface stage elevations were made, and the measured flow volumes (if any) when observations and measurements were made.

**Table 5-4.** Field Observation Dates, Transects Observed, and Lainhart Dam Flow Volumes for the Northwest Fork of the Loxahatchee River.

Date	Transect	Measured Q (cfs)	Q at Lainhart Dam (cfs)
7/27/2004	1	30 - 32	30 - 40
8/03/2004	2, 3, 4	--	38
8/11/2004	1	86	84 - 140
8/12/2004	2, 4	--	114 - 138
8/13/2004	1, 2, 3, 4	--	88 - 94
8/17/2004	1, 2, 3, 4	--	82 - 85
9/09/2004	2	--	339
9/10/2004	1, 2, 3	--	236 - 241
9/14/2004	3, 4	--	182 - 186
9/16/2004	1, 3	--	176
9/23/2004	1, 2, 4	--	287 - 326
9/29/2004	1, 2, 4	--	461 - 476
10/01/2004	2, 3	--	258
12/01/2004	2	--	50

The degree of floodplain inundation at different water stage levels is depicted in the following photographs and cross-sectional diagrams for each of the four riverine transects. Observations are also summarized in **Table 5-5**.



**Table 5-5.** Northwest Fork of the Loxahatchee Riverine Floodplain Flow/Inundation Observations Based on Lainhart Dam Flows.

	Transect ID Number				
Lainhart Dam Flow (cfs)	1	2-1	2-2	3	4
35	N	N	N	N	--
88	N	--	--	N	N
130	N	N	--		Y<1'
177	Y<1'		--	Y<1'	Y~1'
236	Y<1'	Y<1'	--	Y>1'	Y>1.5'
330	Y>1'	--	--	--	--

N = no inundation of floodplain observed.

Y = inundation of floodplain observed.

-- = no observation made.

Surveyed benchmarks were placed adjacent to the river channel at each transect. These benchmarks are identified by numbered metal tags. Transect 1 includes Tags 601, 602 and 609. Transect 2 includes Tags 603 and 606. Tag 607 is located at Transect 3; Tag 609 is located at Transect 4.

**Figures 5-6 through 5-10** are photographs of the river and floodplain at Transect 1 taken over a range of flows ranging from 88 to 476 cfs during the observation period. **Figure 5-11** is a cross-sectional profile of Transect 1 based on survey data on June 2003. Water stage elevations as measured on the dates indicated are depicted. The depth and lateral extent of floodplain inundation is readily evident at each level of inundation. Flows are contained in the main river channel up to and through 88 cfs. That discharge creates an associated river stage of approximately 9.4 feet NGVD. Water levels at that stage remain slightly to well below the lateral ground surface elevations in the floodplain.

## Transect 1

**88 cfs 8/13/04 9:30**

- No Flow Outside of Channel
- Standing Water In Floodplain
- Remnants of Release From G-92 Max.  
Flow = 192 cfs



**Downstream of Stage Measurement site 9:05**



**Tag #601 and #602 9:15**



**Standing Water at 75m West 9:30**

**Figure 5-6.** River Stage Conditions at Transect 1 on 8/13/04 With 88 cfs Discharge at Lainhart Dam.

### Transect 1

114 cfs 8/12/04 12:50

- Water Level At Top of Bank
- Standing Water in Floodplain
- Debris Piled On Banks
- Ebbing Side of Controlled Release From G-92



Downstream of Stage Measurement Site and Tag #602 12:00



Tag #601 and #602 12:00



Standing Water at 75m West 12:15

**Figure 5-7.** River Stage Conditions at Transect 1 on 8/12/04 With 114 cfs Discharge at Lainhart Dam.

### Transect 1

241 cfs 9/10/04 10:40

- Water Over Top of Bank
- No Visible Flow in Floodplain
- A Lot of Debris
- Floodplain Inundated Knee Deep



Edge of Floodplain 10:30



Floodplain Inundated at 75m West 10:50



Measuring Tag #601 10:45

**Figure 5-8.** River Stage Conditions at Transect 1 on 9/10/04 With 241 cfs Discharge at Lainhart Dam.



### Transect 1

288 cfs 9/23/04 2:52

- Water Over Top of Bank
- Visual Flow in Floodplain
- Thigh Deep in Floodplain



Edge of Floodplain at 45m West 2:45



Looking West at 55m East Pole 3:06



Looking Downstream at Tag #601 2:52

**Figure 5-9.** River Stage Conditions at Transect 1 on 9/23/04 With 288 cfs Discharge at Lainhart Dam.

### Transect 1

476 cfs 9/29/04 10:18

- Water Level at Top of Floodplain
- Waist Deep In Floodplain
- Few Cypress Knees Above Water Surface
- Flow Visually Observed in Floodplain



Looking Downstream at Tag #601 10:18

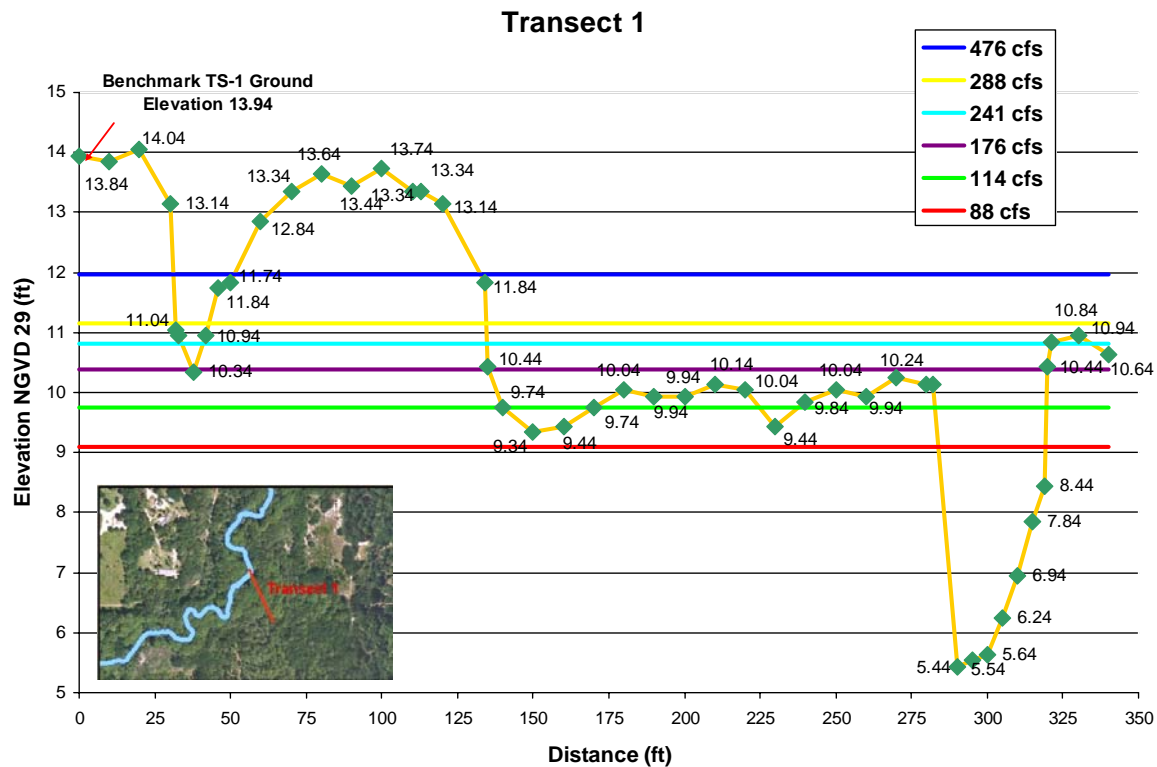


Edge of Floodplain Looking East 10:13



At 75m looking West 10:52 10:32

**Figure 5-10.** River Stage Conditions at Transect 1 on 9/29/04 With 476 cfs Discharge at Lainhart Dam.



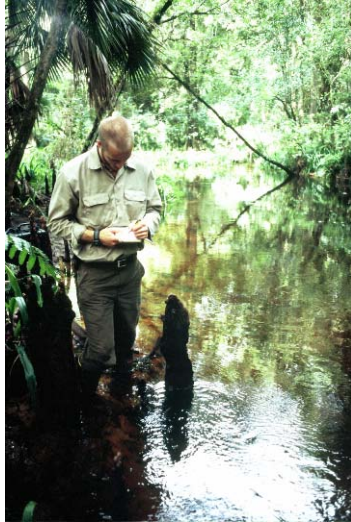
**Figure 5-11.** Transect 1 Cross Section and Observed Inundation Depth and Extent.

**Figures 5-12 through 5-16** are photographs of the river and floodplain at Transect 2 taken over the same range of flows. Transect 2 had two segments. One segment was upstream of Masten Dam and the other was downstream of the dam. **Figures 5-17 and 5-18** are cross-sectional profiles of the upstream and downstream segments of the transect. The profiles depict the depth and lateral extent of floodplain inundation over the range of flows on those dates that water surface elevations were observed and measured.



Transect 2

89 cfs 8/13/04 10:15  
– River Flowing in Bank



Below Masten Dam Next to Tag #603 and  
Stream Flow Measurement site 10:15



MastenDam 10:00



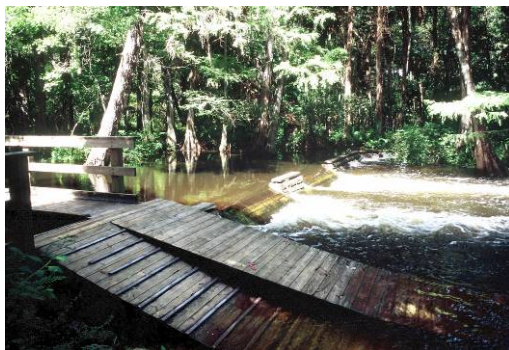
Below Masten Dam measuring Tag #603 10:15

**Figure 5-12.** River Stage Conditions at Transect 2 on 8/13/04 With 89 cfs Discharge at Lainhart Dam.

Transect 2

121 cfs 8/12/04 10:30

– Ebbing Side of Controlled  
Release From G-92



Masten Dam 10:35



Below Masten Dam Tag #603 10:30



Above Masten Dam Tag #606 10:40

**Figure 5-13.** River Stage Conditions at Transect 2 on 8/12/04 With 121 cfs Discharge at Lainhart Dam.

## Transect 2

235 cfs 9/10/04 12:23



Masten Dam 11:56



Below Masten Dam Tag #603 12:23



Above Masten Dam Tag #606 12:00

**Figure 5-14.** River Stage Conditions at Transect 2 on 9/10/04 With 235 cfs Discharge at Lainhart Dam.

## Transect 2

325 cfs 9/23/04 10:02



Above Masten Dam Upstream of Tag #606 10:04



Above Masten Dam Tag #606 10:03



Masten Dam 10:07

**Figure 5-15.** River Stage Conditions at Transect 2 on 9/23/04 With 325 cfs Discharge at Lainhart Dam.



## Transect 2

470 cfs 9/29/04 11:05



Above Masten Dam Tag #606 11:15

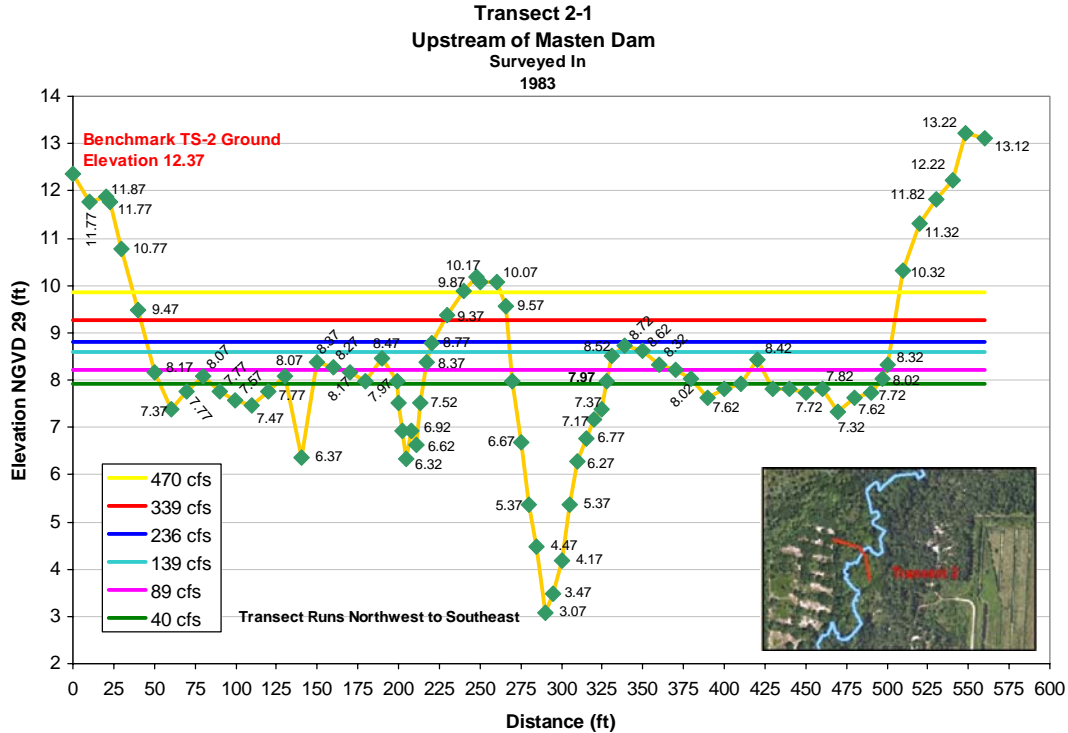


Floodplain Downstream of Masten Dam 11:20

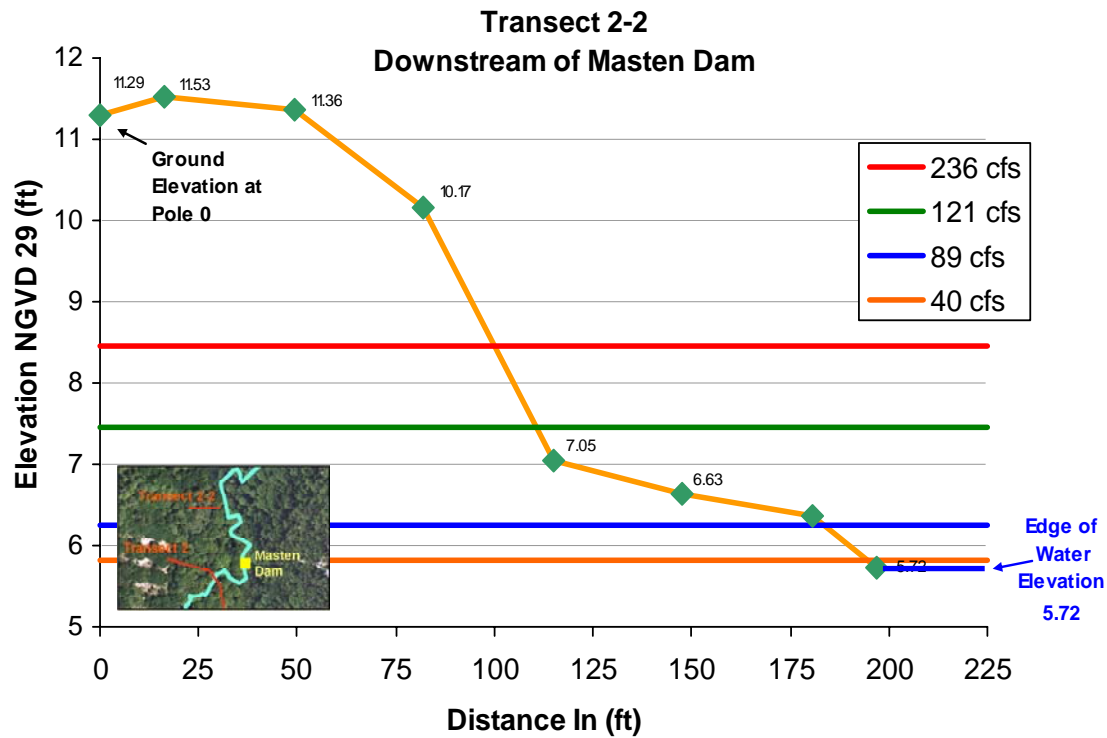


Masten Dam 11:08

**Figure 5-16.** River Stage Conditions at Transect 2 on 9/29/04 With 470 cfs Discharge at Lainhart Dam.



**Figure 5-17.** Transect 2-1 Cross Section and Observed Inundation Depth and Extent.



**Figure 5-18.** Transect 2-2 Cross Section and Observed Inundation Depth and Extent.

**Figures 5-19 and 5-20** contain photographs of the river and floodplain at Transect 3 taken over a range of flows from 81 to 258 cfs. **Figure 5-21** is a cross-sectional profile of Transect 3.

Flows of up to 88 cfs remained confined to the main river channel and braided lateral channels. The water stage elevation associated with that flow is just slightly below that of the riverine floodplain ground elevation. It is apparent that flows in excess of this amount would likely result in some degree of floodplain inundation.

### Transect 3

- 83 cfs 8/17/04 9:20
- 91 cfs 8/13/04 11:20
  - Channel Flowing Within Banks
  - Little to No Flow in Braided Streams



Braided Channel at 35m North  
8/13/04 11:54



Flow within the channel: 8/17/04 9:33



Stream Flow Measurement Site 8/13/04 11:33

**Figure 5-19.** River Stage Conditions of Transect 3 on 8/13/04 and 8/17/04 With 83 and 91 cfs Discharge at Lainhart Dam.

### Transect 3



On Transect at 15m Looking West Towards River 9/14/04  
11:45



Stream Flow Measurement Site 9/14/04 12:05

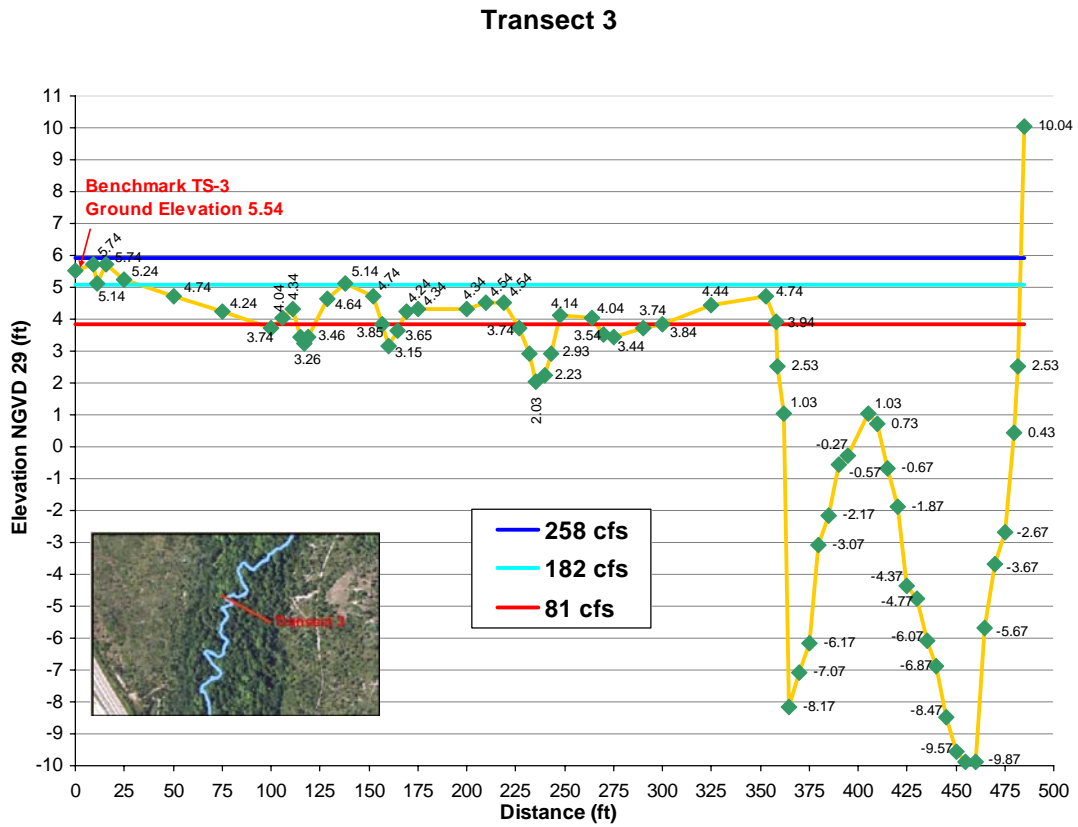


Looking South at 35m North on Flowing Braided  
Channel 9/10/04 2:29



Edge of Floodplain 9/10/04 2:45

**Figure 5-20.** River Stage Conditions at Transect 3 on 9/14/04 and 9/10/04 With 182 and 229 cfs Discharge at Lainhart Dam.



**Figure 5-21.** Transect 3 Cross Section and Observed Inundation Depth and Extent.



**Figures 5-22 through 5-25** are photographs of the river and floodplain at Transect 4 taken over a range of flows from 83-461 cfs. **Figure 5-26** is a cross-sectional profile of the transect. It depicts the depth and lateral extent of floodplain inundation observed over the range of flows observed during the course of this floodplain evaluation.

#### Transect 4

- 83 cfs 8/17/04 3:30
- 93 cfs 8/13/04 12:49
  - No Flow Outside of Channel



Stream Flow Measurement Site 8/17/04 3:42



Stage Measurement Site Tag #608 8/13/04 12:56



Double Logs in Channel 8/13/04 1:00

**Figure 5-22.** River Stage Conditions at Transect 4 on 8/13/04 and 8/17/04 with 83 and 93 cfs Discharge at Lainhart Dam.

#### Transect 4

- 186 cfs 9/14/04 1:25
  - No Visual Flow In Floodplain
  - Knee Deep
  - Dry Hummocks



Site of Double Logs in Channel 1:34



Stage Measurement Site Tag #608 1:26

**Figure 5-23.** River Stage Conditions at Transect 4 on 9/14/04 With 186 cfs Discharge at Lainhart Dam.

#### Transect 4

- 309 cfs 9/23/04 11:36
  - Visual Flow Through Entire Floodplain
  - Waist Deep
  - Causeway Still Dry



Edge of Floodplain 11:05



At 25m South Looking Towards Floodplain 11:20



Stage Measurement Site Tag #608 11:40

**Figure 5-24.** River Stage Conditions of Transect 4 at 9/23/04 With 309 cfs Discharge at Lainhart Dam.

#### Transect 4

- 461 cfs 9/29/04 12:30
  - Visual Flow Through Entire Floodplain
  - Over Waist Deep
  - Water Flowing Throughout the Floodplain
  - Water Hickory at 85m 20" Deep



Water Hickory 12:51

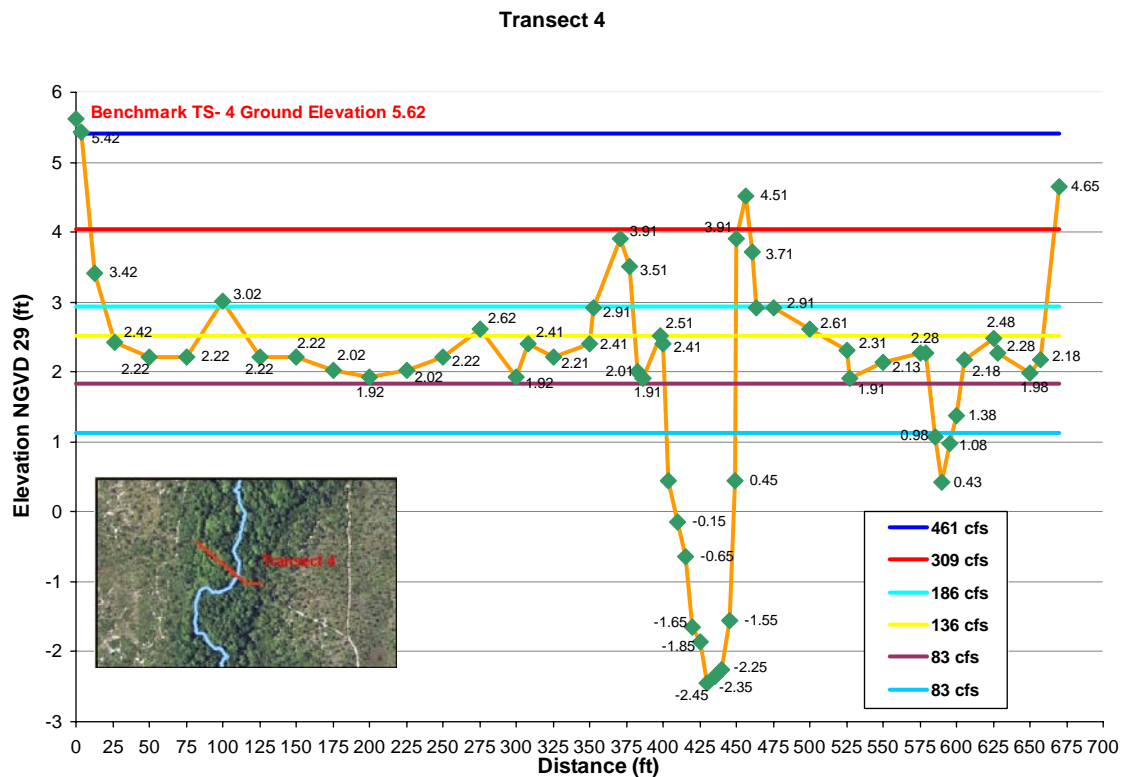


Edge of Floodplain Looking North 1:05



Stage Measurement Site Tag #608 12:32

**Figure 5-25.** River Stage Conditions at Transect 4 on 9/29/04 With 461 cfs Discharge at Lainhart Dam.



**Figure 5-26.** Transect 4 Cross Section and Observed Inundation Depth and Extent.

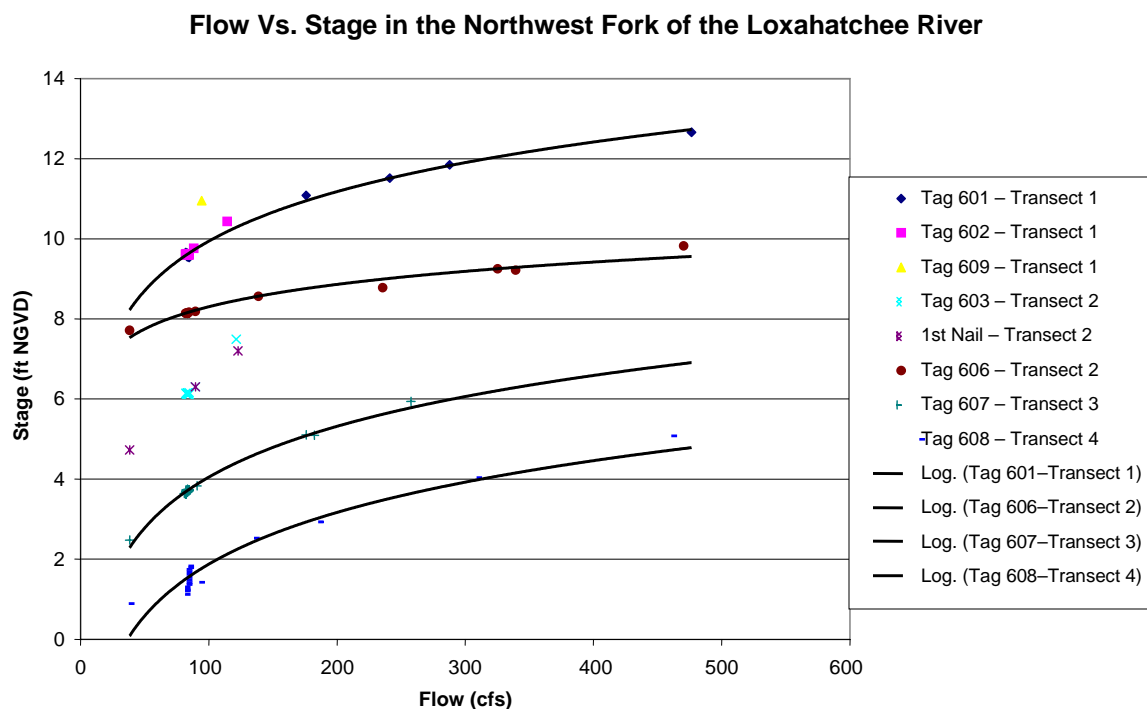
Of the four transects, Transect 4 is the farthest downstream and the water stage elevations are impacted by daily tidal regimes. The stage/discharge relationship at 84 cfs clearly depicts the degree of tidal influence on the particular date that these measurements were made. While not directly impacted by the saline waters coming upstream from Jupiter Inlet, the water surface at this location is obviously raised by the stacking of the water as the Lainhart Dam discharge meets the incoming tidal prism further downstream. No floodplain inundation was observed nor is any inundation expected at the river stages associated with the 84 cfs discharge. This was the case at both low and high tides.

## GENERAL OBSERVATIONS AND CONCLUSIONS

The previous figures depicting the observed degree of floodplain inundation versus stage at the four transects are consistent with the conclusions and calculations that were provided by Gonzalez (2005) after the earlier described controlled release study. At all four transects discharges of 90 cfs or less seem to result in little or no overbanking of the main river channel and resulting flooding of the floodplain floor. Conversely, discharges of 100 cfs or greater would appear to begin to consistently spread water over at least some of the floodplain floor.

Measured river surface stages at the four transects plotted against discharge at Lainhart Dam yield a series of practically parallel curves as depicted in **Figure 5-27**.





**Figure 5-27.** Observed Surface Water Stages at Various Discharge Rates Over Lainhart Dam. Tag Numbers Refer to Surveyed Benchmarks Placed Adjacent to the River Channel at the Study Transects.

The stage/discharge relationship at Transect 2 is distorted to a somewhat flatter relationship on the upstream side of Masten Dam at low flows and a steeper relationship on the downstream side. The impacts of the dam seem to be dissipated by the time flow reaches Transect 3. Tidal fluctuation has imperceptible impacts at Transect 2 (downstream section). Tidal fluctuation had slight impact at Transect 3 during the 8/17 Controlled Release Study. Tidal fluctuation appears to have a regular and noticeable impact on water stages at Transect 4.

Inundation depths in **Table 5-6** are calculated based on the measurements used to develop the Flow versus Stage curves depicted in **Figure 5-27**. The median and range of those observations were used and compared with predominant floodplain floor elevations derived by using actual surveyed elevation points measured for the portion of the floodplain that exhibited vegetation and topography typical of that habitat type at each of the four transects.

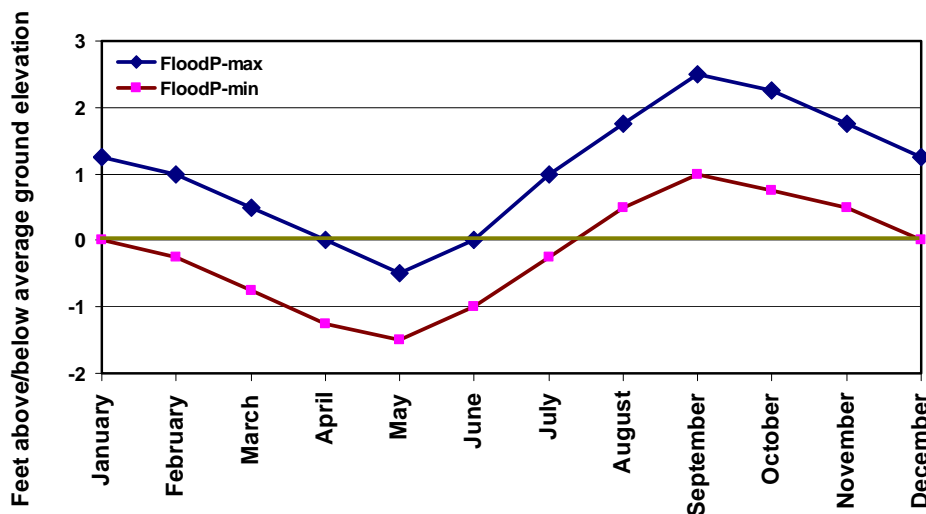
**Table 5-6.** Riverine Floodplain Inundation Depth Resulting From Increasing Flows as Measured at Lainhart Dam (in feet  $\pm$  natural variation).

Flow at Lainhart Dam (cfs)	Transect 1	Transect 2 upstream of Masten Dam	Transect 3	Transect 4
65	0.0 $\pm$ .5	0.2 $\pm$ .2	-0.5 $\pm$ .4	-0.9 $\pm$ .6
90	0.1 $\pm$ .6	0.4 $\pm$ .1	0.0 $\pm$ .2	-0.6 $\pm$ .6
130	0.6 $\pm$ .3	0.7 $\pm$ .2	0.6 $\pm$ .2	0.2 $\pm$ .6
250	1.6 $\pm$ .3	1.1 $\pm$ .2	1.9 $\pm$ .2	1.3 $\pm$ .2
330	2.1 $\pm$ .2	1.4 $\pm$ .2	2.6 $\pm$ .2	1.9 $\pm$ .3
Floodplain Floor Elevation (ft)	9.86	7.84	3.90	0.26

Depth of inundation was estimated by subtracting the floodplain floor elevation for each transect from the median and range of measured river surface elevations from which the stage/discharge curve relationship was created. These calculated values agree favorably with the field observations over the study period and described earlier in this chapter.

### Dry Season Discharge Scenario

The basic assumption underpinning the strategy and approach for performing this evaluation is the concept that by achieving hydrological performance measures for “Floodplain Swamps” as depicted in **Figure 5-28** we will concurrently meet and achieve hydrologic performance measures for the entire floodplain community during the dry season. The two lines in the figure depict the idea that the maximum and minimum surface and groundwater stages set the boundaries for the hydrological conditions necessary to produce a healthy floodplain swamp vegetative community. Maintaining stages at some level between the two lines is the appropriate management goal for the system. Based on measurements and observations performed during this analysis, it seems clear that dry season (December to May) flows over Lainhart Dam should not exceed 95 cfs, except under severe storm rainfall conditions. Flows in excess of 90 cfs should be avoided, if possible from March to June. A normal seasonal variability over a range of flows from 60 cfs to 90 cfs is desirable for the riverine floodplain in the dry season. Inundation of the floodplain during the dry season is considered undesirable in that it would impede seed germination and seedling survival of the desired floodplain community species.



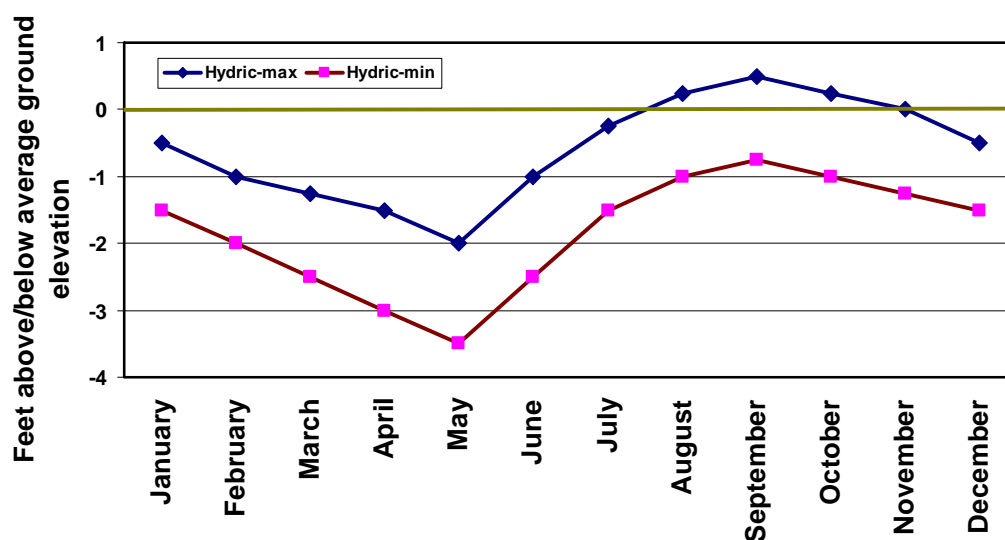
**Figure 5-28.** Annual Hydrological Performance Measures for Floodplain Swamps in the Northwest Fork of the Loxahatchee River.

### Wet Season Discharge Scenario

The other basic assumption governing floodplain vegetative community health measures is that achieving hydrological performance measures for “Hydric Hammocks” will concurrently meet and achieve hydrologic performance measures for floodplain swamps during the wet season. Protection of the hydric hammock vegetative community during the wet season provides hydrologic targets conducive to the success of these systems and also the riverine floodplain community that lies at lower elevations.

**Figure 5-29** depicts the range of surface and groundwater stage elevations that are necessary to achieve a healthy hydric hammock community. The two lines are the maximum and minimum water surface elevations, which, if managed appropriately, water stage elevations should be maintained within. The presence of hydric hammocks within and on the periphery of the riverine floodplain suggests that the historical river hydrology has allowed this to occur. Maximum flows during the course of these observations pushed the upper limit of that hydrograph for the hydric hammocks. These were the results of extreme events associated with the floodplain feeling the successive effects of Hurricanes Frances and Jeanne and Tropical Storm Ivan in the Fall of 2004. Excessive inundation will result in a change in community type from hydric hammock to a more wet-adapted community.

Flows at Lainhart Dam of 130 to 300 cfs for four months during the wet season should be sufficient to provide the appropriate degree of wet season riverine floodplain inundation. Wet season is identified here as extending from June through November.



**Figure 5-29.** Annual Hydrological Performance Measures for Hydric Hammocks in the Northwest Fork of the Loxahatchee River.